PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

July, 1944
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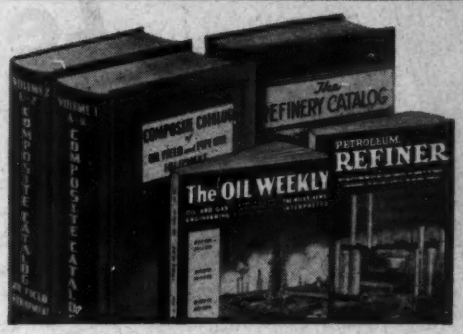

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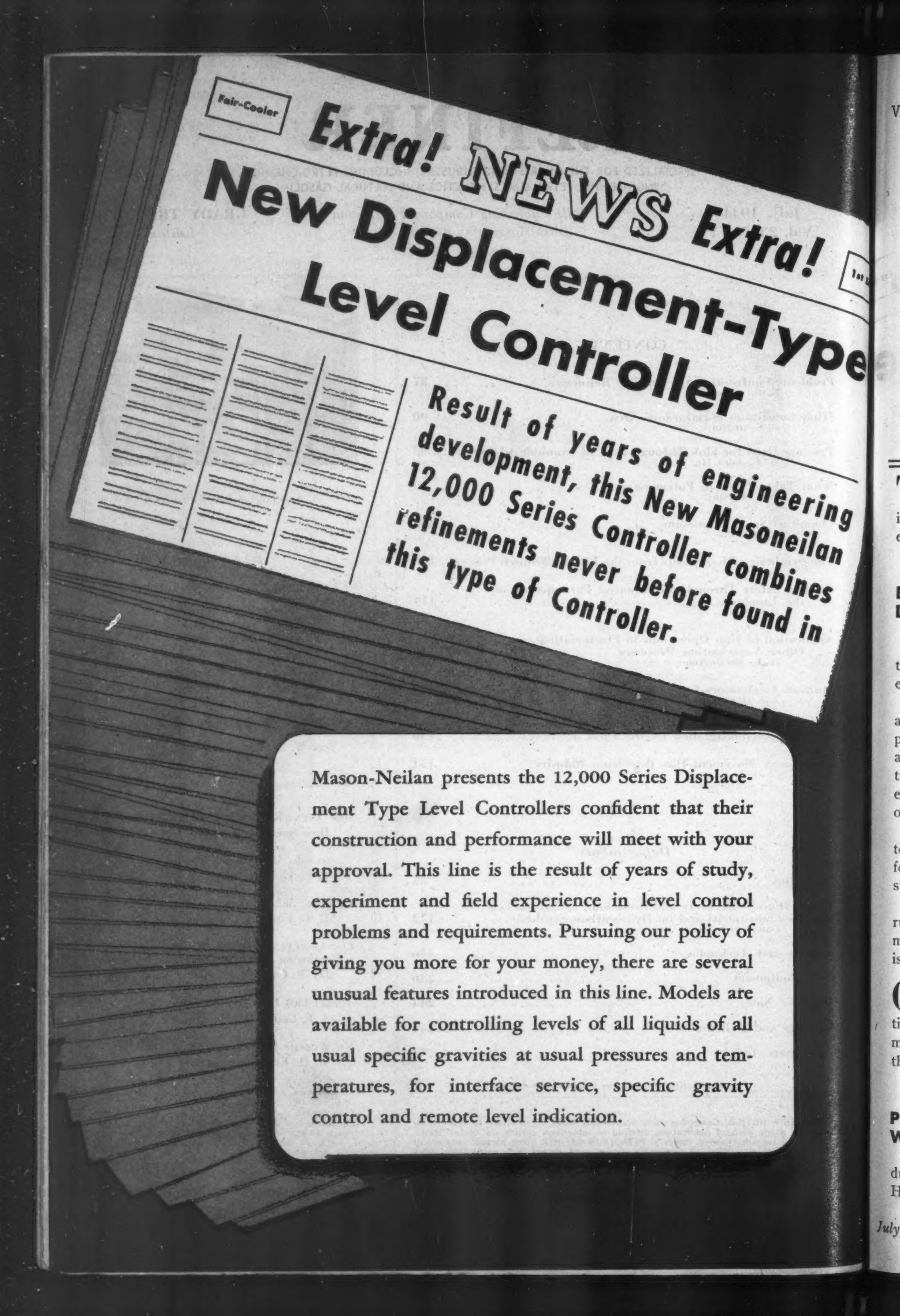
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VOLUME 23, NO. 7 JULY, 1944

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REFINER

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THE LOOK BOX

THE fact that the military dares make known its need for 100-octane aviation gasoline is ample evidence that it promises nothing disastrous.

Bad But Not Disastrous

The sudden realization of shortage, however, is evidence that efforts to determine requirements of this product are not satisfactory. It may be that calculation is impossible. There have been several complaints to the effect that military authorities have not given estimates of demand.

Certainly the refining industry considered its accomplishment adequate. Daily output of this prime product now stands at 400,000 barrels daily and only 80 percent of the special plant construction is complete. If more had been asked and the equipment provided for plant capacity, the amount of gasoline could have been greater.

Although it is not disastrous, it is disconcerting to realize that plans for an invasion went along for two years and that within two weeks after its start there was a shortage of premium gasoline.

Fortunately butylene can be diverted from the rubber program without disaster. Rubber-goods manufacturing plants are under staffed and there is a stockpile of crude synthetic rubber.

OF ITS volition the Petroleum Administration for War reduced its original estimate of money requirements from The Congress, a move that deserves praise from the industry it serves.

Praise Worthy

The original budget was set at $6,550,000, which would have provided for increase in personnel. Subsequent to hearings before the House appropriations committee, the amount was reduced to $6,000,000, which was approved by the House of Representatives.

The report of this committee to the House included this explanation, that PAW had made "consolidations with the organization, improved procedure and otherwise brought about economies."

Even in a day of spending in billions, a saving of a half million dollars or a reduction of that much in money requested still seems like a substantial sum. In addition PAW has set an example which it is hoped will find matching efforts as other agencies come to the day of seeking funds.

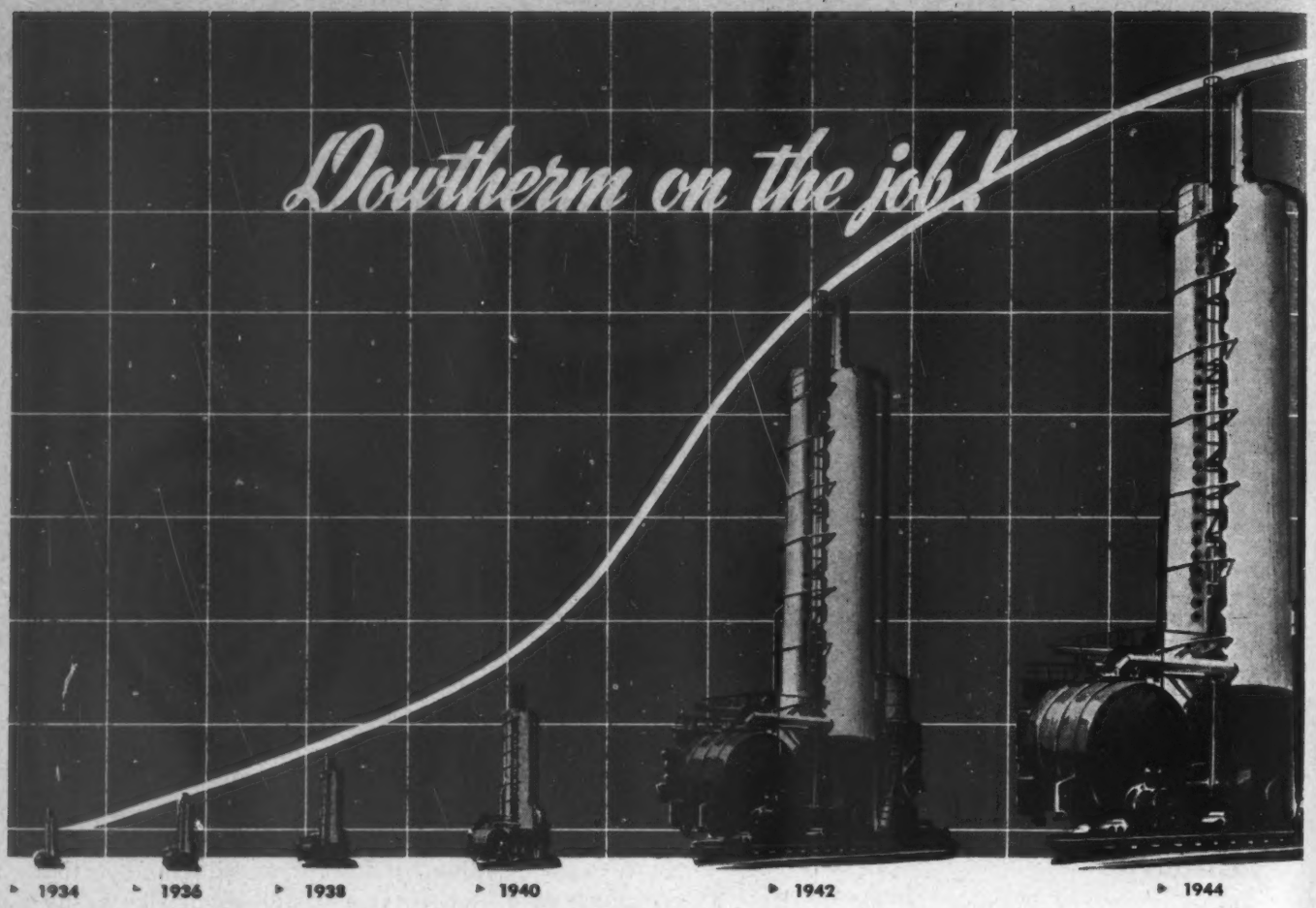
FEAR of catalytic processes is little short of preposterous. It rests with owners of small refineries, who assume that only large units will permit catalytic processing.

Why Fear Progress

This is ill founded. Owners of the processes are confident of adapting their units to small installations. The processes now in large-unit operation will be adapted. In addition several other processes, not yet announced, will be available when conditions permit installation.

It seems logical that the refining industry will function substantially as now built for the duration. By the end of the year daily output of 100 octane aviation gasoline should reach 600,000 barrels. The industry is furnishing another million barrels daily of other petroleum products. There will be little cause for plant expansion while this requirement must be met.

But plans for introducing new processes for small-scale installations and adaptation of present catalytic processes to small-scale building are going forward. Equipment for these smaller installations will be feasible by the time material is available for building.



TEN YEARS OF CONTINUOUS INDUSTRIAL SERVICE

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Another error in thinking is the assumption that only catalytic cracking will prevail in the future. Its efficiency is evident and its growth assured, still it has demonstrated nothing to spell the doom of thermal processes. The plant with a modern thermal-cracking still can produce premium products with the assistance of polymerization, alkylation, cumeme and codimer.

Refining will advance but it will not destroy. Destruction will come only where there is refusal to advance.

The Other Way Around

WE HAVE heard and read a great deal recently of the problem of creating postwar jobs. The emphasis has been on *jobs*. Surveys have been made of many concerns asking how many people they can employ after the war. Maybe this will be of some help, but we believe the emphasis should be on setting the stage for *prosperity* after the war then jobs will surely follow. *Jobs do not create prosperity; prosperity creates jobs.*

If in the postwar period we have a sound government in which business men have confidence—confidence that the rules will not be changed from day to day—confidence that government is to be the umpire of business rather than the administrator of business—confidence that taxes are to be fixed so that the man who starts a business enterprise, large or small, can hope to keep part of his earnings, if his venture is successful—then we will have set the basis for an upsurge in business that will provide jobs.

Given a sporting change to make money and a chance to keep some of it, American ingenuity will devise products and create a demand for these products which means healthy industrial activity, which in turn means broad employment—employment that results in giving the people something they want—employment that will reduce, rather than add to, the tax burden.

Slightly Expensive

FOR the sake of national security it is well that the Army has not been compelled to provide all of the oil requirements for global military operations of the United Nations. At least it is fortunate, if the cost of oil from the Canol project should apply to the 1,500,000 barrels now required each day for these operations.

Under such volume and at the cost of $15.9067 per barrel, petroleum products alone would hit the staggering total of $23,860,050 for each day's supply. Over a year that will add up to a neat sum even in comparison with the gigantic expenditures at which this war is being fought.

It was the testimony of General L. D. Worsham before the House appropriation committee in June. He and others had come to ask for $16,500,000 for operating the Canol project for a year. Interpreted in cost-per-barrel expense of Canol became evident.

On the Rebound

REASONING in behalf of a higher price for crude oil has seemed both logical and just. Still it now seems that it would have been beneficial had no effort been made to gain the higher price through statute. However well founded the plea, The Congress is not disposed to grant the request.

Justice of the plea is admitted in OPA, which proposes to grant subsidies (higher prices for oil from low-output wells). This is where the effort to gain a higher price has been harmful. The plea has been converted into an instrument, which will bring credit to the bureaucrat. A man or a set of men now have the financial welfare of an oil producer at their mercy.

The proposal is linked with well output but this is something that can be controlled. A well of low output may be more profitable than one of higher output. The tendency will be to produce less oil, while the need of the hour is for producing more oil.

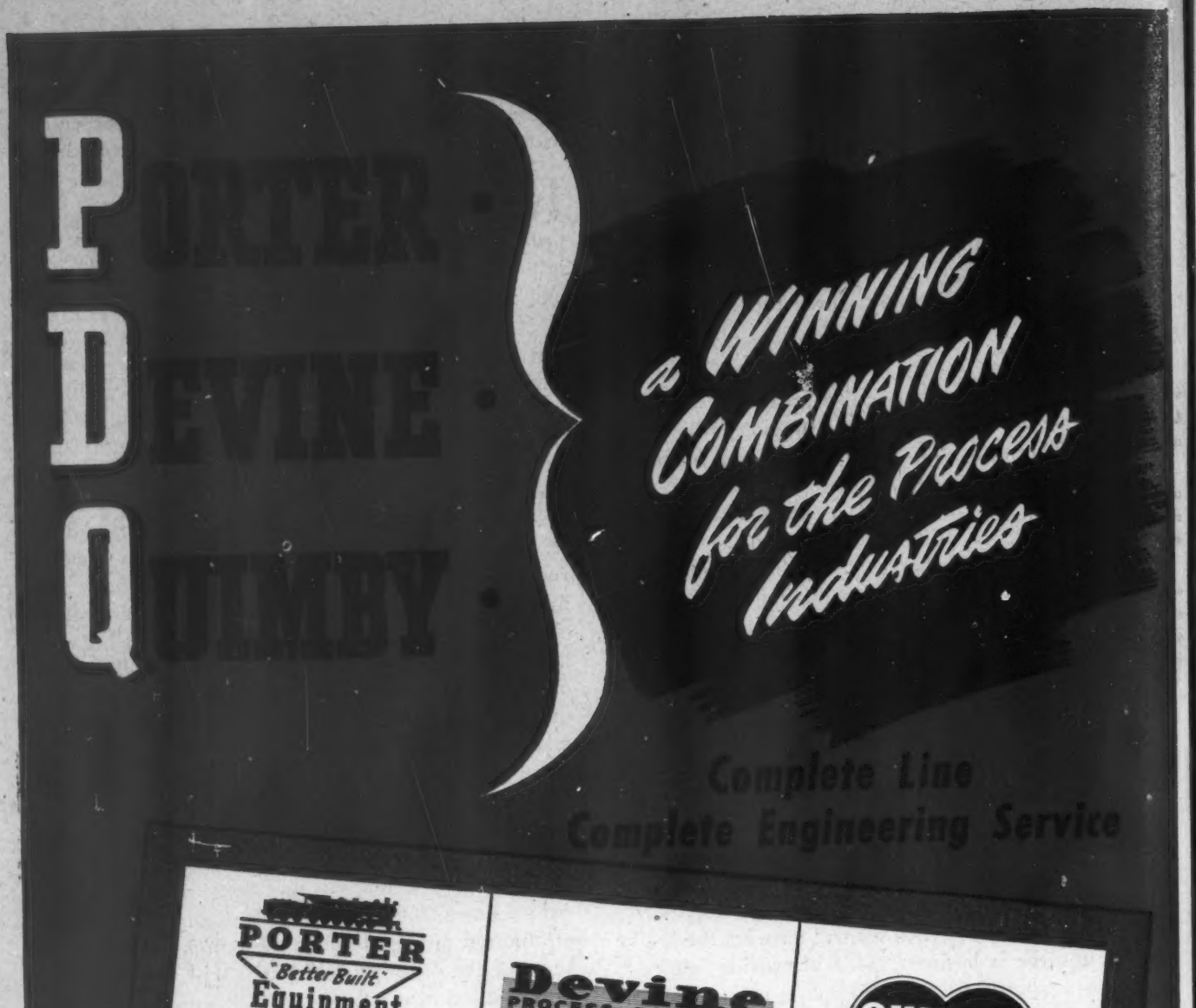
Nothing has been said as to the value of a barrel of oil in use. Oil from a well making three barrels a day and drawing a bonus will make no more and no better gasoline than oil from a well which flows 100 barrels daily. Only the cost of production differs. Paying the bonus may appease some of the oil producers but it will not stimulate the production of oil and it will not contribute to the military effort, the one and only purpose in setting up OPA.

Gone to The War

LIKE the other crafts, printing has seen its men go off to war. An idle press means an active gun. However unsatisfactory a late publication may be, complaint is out of order. The necessity of full gun crews is not to be compared with the desirability of full press crews.

PETROLEUM REFINER takes its turn each month in a plant which has made its contribution to the military, both in personnel and in supplying printed matter for the armed forces and war agencies. Although no apology seems justified, it is proper to accept the condition as undesirable. Publication date will be met when the fortunes of war permit men to come home.

Inability to keep on schedule is as objectionable in the printing plant as it is in the publisher's office. From type setting to binding the men and women in the plant know why the publication is late, and do not like it.



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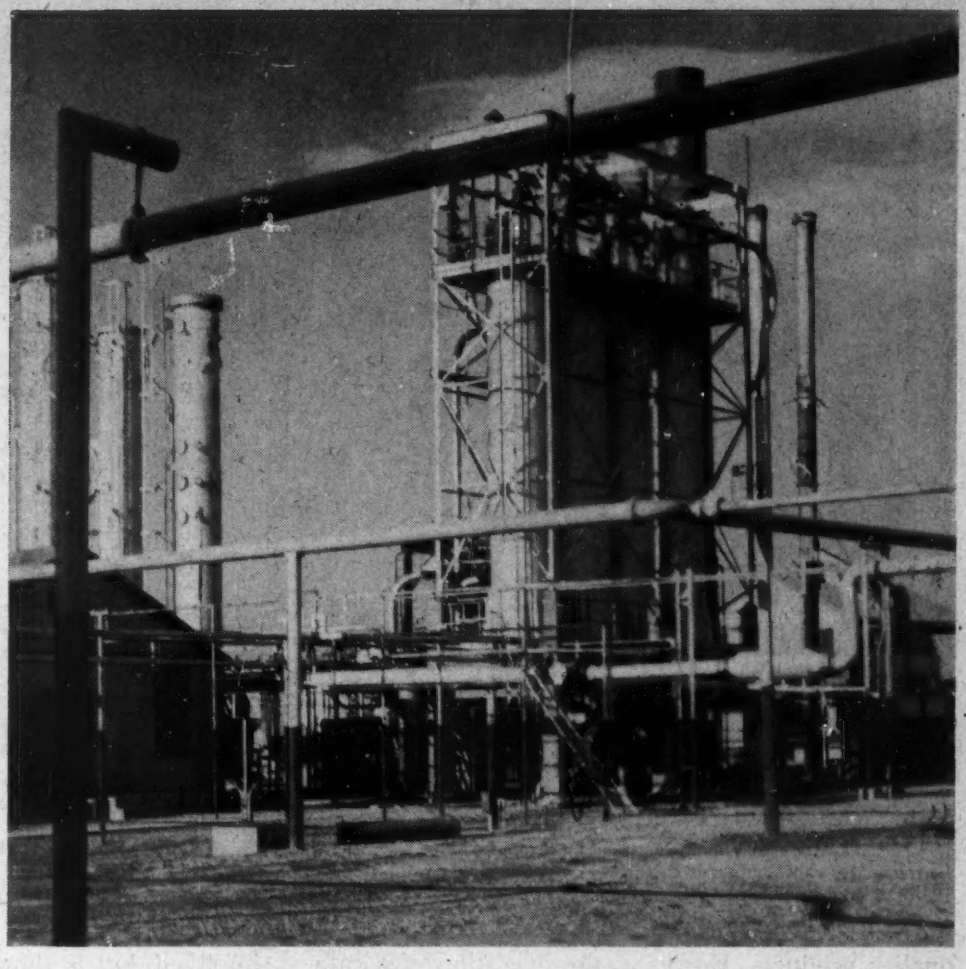


Polymerization unit in the refining plant of the Shamrock Oil & Gas Corporation. This process came into wide use in small plants.

The author points to more recent processes, which will be available to the small refining plant after the war.

Through the purchase of high octane blending agents, the owner of a small refining plant will have another means of keeping in step with the motor fuel quality trend.

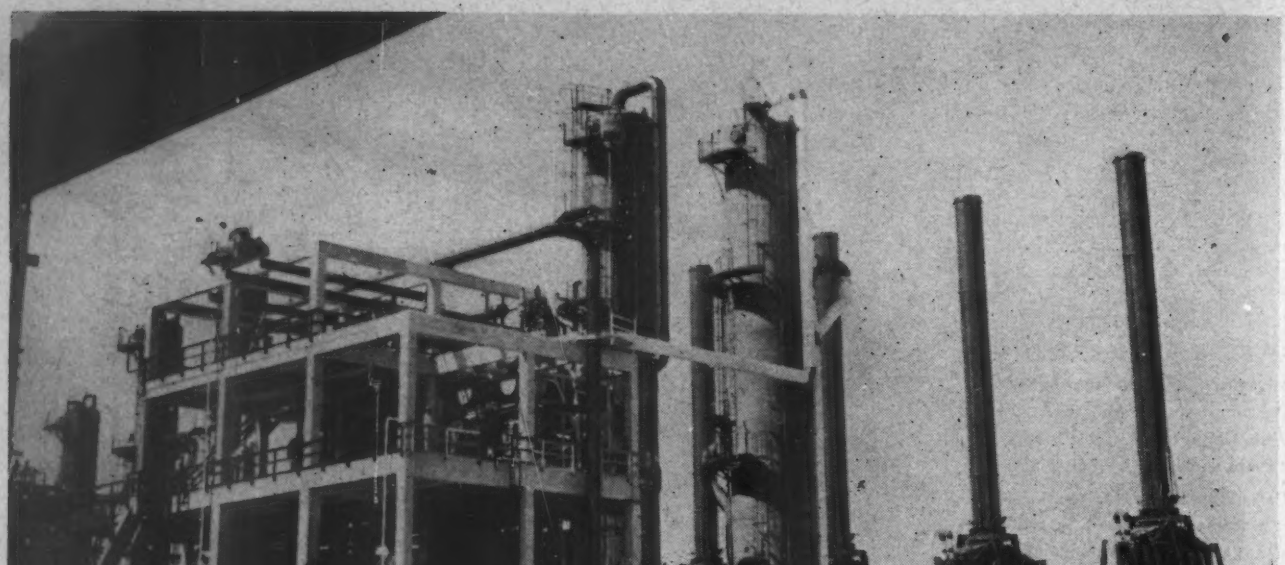
Problems Confronting the Smaller Refineries

R. G ATKINSON
Technical Adviser, The Shamrock Oil and Gas Corporation

THE refining companies that do not have a highly developed research department of their own must look to other sources for developments whereby they may meet the competition of constantly improved products and more efficient processing methods. Attempts to solve these problems by means of research on a small scale will in all probability encounter insurmountable difficulties, since the basic processes which necessarily must be used; that is, catalytic cracking, isomerization, alkylation, and others, are surrounded and covered by patents. However, since nearly all of these newer processes are open to the independent refiner on a royalty basis, there is intended to be at hand a means whereby the smaller refineries can install and benefit by modern technological improvements. If the royalty payments are not too expensive, they may be considered by the small refiner as his cost of research which he has not been able to do individually, and in this event, the royalty payments should find their way back into and create further research. The system, thus constituted, should provide an organized and effective means of supplying research service to the entire industry.

As crude oil becomes more valuable, and developments in refining are directed toward obtaining higher yields of higher-quality products, it may be necessary to make the fullest use possible of all modern processes which can be applied in order for the small refiner to remain in business. In this regard, the large-scale application of catalytic cracking, which is presently taking place, is generally expected to have a great effect on processing, both in the large plants operating the large catalytic units and in the small plants which must make some changes to keep their products on a competitive market.

Since the indications are that the quality of future gasoline may be closely related to the performance of catalytic cracking units, it seems appropriate to try to estimate what effect this development may have on the specifications of the gasoline to be sold in the future. It has been estimated that among the major catalytic processes there are approximately 100 units constructed, or in varying stages of completion. These plants probably will continue to operate in the postwar period, because they exist ready to operate and are in a position to furnish higher-



This alkylation unit in the new refining plant of the Cities Service Refining Corporation, Lake Charles, Louisiana, is part of the total capacity, whose output is calculated as sufficient for raising the octane rating of the motor gasoline total by 3.1 octane numbers. Purchase of alkylate and other blending agents from major refining companies is another approach to raising quality of small plant gasoline output.

quality products. However, the operation of a catalytic cracker is decidedly more complicated than thermal cracking has been in the past, and, therefore, the cost of operation is expected to be relatively high. This factor may cause the market price for the higher-quality gasoline to be high enough to allow the smaller refiner to make additional expenditures to improve the quality of his products.

The existing catalytic-cracking units should have a charge capacity of about 1,000,000 barrels per day, from which they may produce a yield of 80-octane pressure distillate equal to about 40 percent of the volume of the charge. The remaining 60 percent will be largely refractory stock which probably will be processed in thermal-cracking units to produce the same quality of pressure distillate and by the same method by which it was cracked before the advent of catalytic cracking. Assuming the above to be true, the total over-all maximum effect of these facilities for catalytic cracking would be to increase the octane number of 400,000 barrels per day of products from an average 66-octane number formerly made by thermal cracking to an 80-octane number for the catalytic product. If this 14-point increase for 400,000 barrels per day is uniformly distributed over the entire gasoline production (assumed 1,800,000 barrels daily), there would result an average increase of 3.1 points in the octane number of all the gasoline. Thus, where the industry used to manufacture a house-brand gasoline of 74- to 76-octane number, it may be possible to manufacture 77- to 79-octane number, and the small refiner must, therefore, find a way to keep pace with these developments which may take place soon after the war ceases.

The estimate made above is admittedly oversimplified, but is thought to be presented as clearly as can be done under present circumstances. Many estimates of what the octane of postwar gasoline will be have appeared in the petroleum literature. These estimates have been based on many different lines of reasoning, and most of them seem to agree that about 2 years after war, house-brand gasoline will be raised 2 or 3 octane numbers higher than was specified before the war.

There are several ways by which the small refiner will be able to meet the increased quality demanded by a future competitive gasoline market. One of these ways may be by the installation of some catalytic-cracking capacity on a small scale. The catalytic-cracking process known as the Cycloversion Process may be particularly applicable in this respect. This process differs from other major catalytic-cracking processes installed in this country in that it is carried out by means of a smaller installation of ordinary refinery equipment. Another process that may have much merit for application by the smaller refinery is the Suspensoid Catalytic Cracking System, recently described by Foster.[1] While this process seems to give somewhat less octane improvement than our major catalytic-cracking processes, it appears to be somewhat simpler in operation and applicable to smaller plants.

In connection with getting a high degree of improvement in quality of product from a small installation of equipment, the possibilities of catalytic reforming should get thorough consideration. A catalytic reforming process applied to the heavy ends or high-boiling fraction of pressure distillate may enable a refiner to produce a gasoline of superior

engine performance by catalytic treating of only a fraction of the total output. Wagner has pointed out that the improvement obtained by this means may be very much greater than ordinarily has been assumed; since improvement in lead susceptibility and engine performance will result in addition to the expected improvement of octane number.[2] It has been demonstrated by an extensive series of tests that the higher-boiling alkyl aromatic compounds which are formed by catalytic cracking give a much better motor performance than the olefins of similar boiling range which ordinarily occur in the higher-boiling fractions of thermal pressure distillate. In regard to the lighter fractions of gasoline, however, it has been found that the lower-boiling-point olefins give a motor performance almost equal to that of catalytically cracked material.[3] It is thus possible to manufacture a gasoline of superior motor performance by blending catalytically reformed material which distills in the upper part of the gasoline boiling range with lighter fractions which may be obtained from ordinary thermal pressure distillate.

The construction and operation of small alkylation plants may prove practical and should be considered thoroughly by the smaller refineries. There probably will be ample quantities of isobutane available in the postwar period at an attractive price, which can be combined with quantities of propane, butene, and pentene, when available, to form very high quality blending constituents. An alkylation plant, by making use of isoparaffins as well as unsaturates, will produce a much greater quantity of product of higher quality than was produced by the widely used small-scale polymerization plant. Another way that a refiner who is deficient in octane may be able to relieve his situation is by the purchase of high-blending-value constituents. Such products as alkylate, codimer, isopentane, and catalytically cracked distillate may be made obtainable to the small refiner to some extent for the purpose of raising the octane number of motor gasoline. These products which have high blending value are worth somewhat more to a refiner than the sales price of his gasoline due to the saving in tetraethyl lead which results from their use. For example, at a market price of gasoline of 6 cents, alkylate, when used in a motor gasoline blend to the extent of 10 percent, will in most cases have a value to the refiner of 8 cents or 9 cents per gallon. Since there may be excess alkylation-plant capacity beyond that which is required to furnish the necessary postwar aviation gasoline, it is possible that some of these plants will be operated even though the price which they obtain for their product is based on the value of alkylate in blending automotive motor fuel. Also, a refiner who is deficient in octane can afford to pay somewhat more for isopentane than he could pay for natural gasoline of the same vapor pressure. For this reason, some of the excess isopentane production over what is used in aviation fuel may be sold as such instead of its going to its previous market as a constituent of natural gasoline.

The solution to the problems of the small refiner in the postwar period seems to be largely dependent upon his ability to negotiate for and install new processes which can be made applicable on an economic basis to his individual situation, and it depends, also, upon his ability to negotiate for sufficient quantities of special blending constituents, on an economic basis, to meet the expected change in quality of postwar gasoline.

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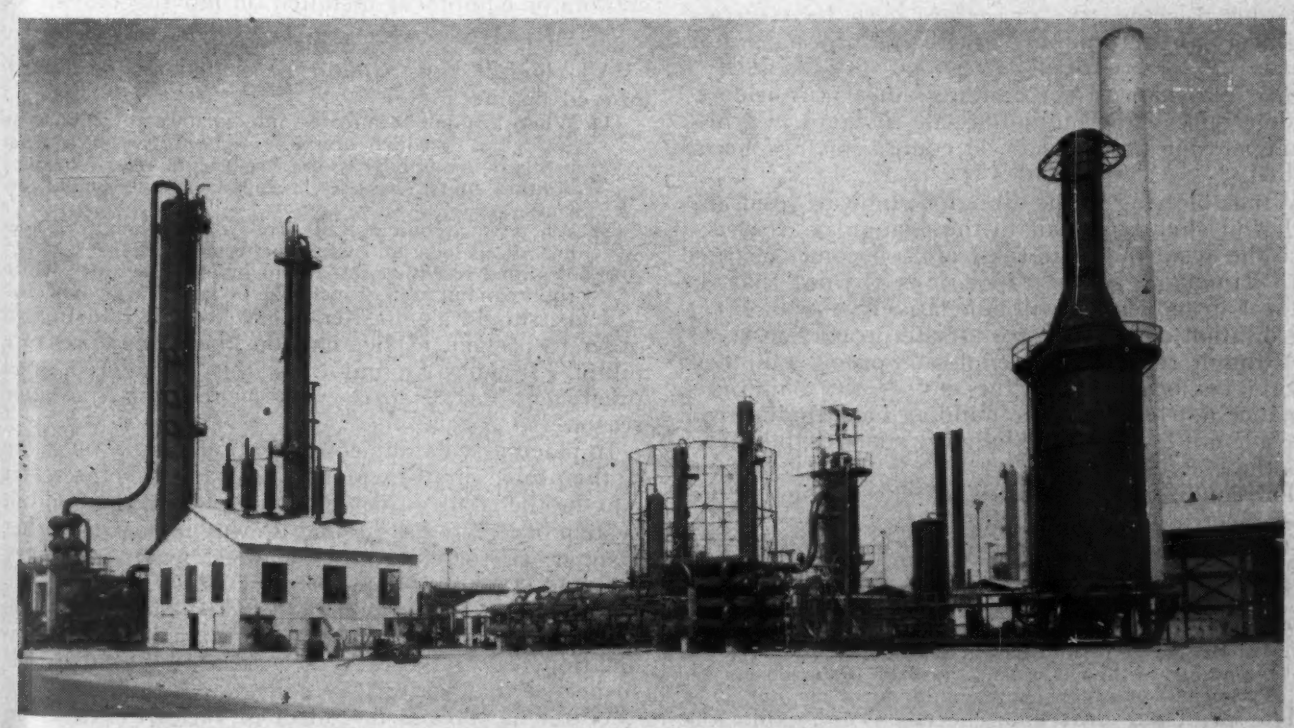

Codimer is now made in many smaller plants. Much of it goes to the few hydrogenation plants, where it becomes hydrocodimer, a still more potent octane blending agent. A possibility of the postwar period will be the exchange of high quality raw materials, butanes and butylenes, for finished blending agents such as hydrocodimer. The unit above is the recently completed hydrogenation plant of Shell Oil Company, Wilmington, California.

What Constitutes a Hazardous Area in the Petroleum, Rubber and Chemical Industry?

What Constitutes Explosion-proof Equipment?

G. G. GRIFFIN
Manager, Product Engineers, Southwestern Division, Crouse-Hinds Company

EXTREME precaution should be taken in the original electrical design of plants with hazardous areas to prevent loss of life, property, and interruption of output. The practice of experienced electrical engineers in the petroleum, rubber, and chemical industries is to install explosion-proof equipment in all locations in which flammable volatile liquids, highly flammable gases, mixtures or other highly flammable substances are manufactured, used, handled or stored, because these flammable materials cannot be controlled after they have escaped from their containers. United States Army Engineers have adopted a standard requiring that all electrical equipment, including service equipment that is not explosion-proof, be located not less than 50 feet from any building in which highly flammable substances are handled; also all service conductors in such areas must be underground.

This requirement was adopted to prevent possible ignition of gases or vapors by arcs caused by broken conductors or accidental grounds.

Figure 1 shows the procedure used by electrical engineers in determining the extent of hazardous areas.

Size and shape of the building must be considered in determining the minimum safe distance at which non-explosion-proof electrical equipment may be installed.

Winds blowing in the directions indicated will disturb, but slightly the air in the triangular areas.

In the event the air in these areas becomes charged with flammable gas or vapor, it is obvious that the natural air movement will be relatively slow in effecting dilution of the mixture to safe proportions.

A rough rule is: Non-explosion-proof equipment should be located from the end of the building a distance not less than the building's width and from the side not less than the building's length, but never less than 50 feet.

The conditions that exist when an explosion occurs from electrical causes usually are:

(1) Presence of gas in the immediate vicinity of electrical devices.
(2) Entrance of gas into the device enclosure by breathing or otherwise.
(3) Ignition of the gas by arcs due to normal functioning of the device or by an insulation failure.
(4) Inability of the enclosure to restrain the explosion and prevent issuance of flames or dangerously hot gases.

The principal difference between non-explosion-proof and explosion-proof electrical devices is that the latter have the ability to restrain the explosion and prevent issuance of flames and dangerously hot gases.

To protect a plant and workers from fire and injuries, all explosion-proof equipment should be constructed in accordance with requirements of Underwriters Laboratories, Inc.; also electrical equipment should be installed in accordance with the latest issue of the National Electric Code. Protection then is assured at minimum cost and the best the art affords.

In locations judged to be hazardous the following provisions should be observed:

(1) Transformers should be installed outside of the hazardous area.
(2) Service equipment and panel boards should be of explosion-proof type and installed as required by the National Electric Code.
(3) Conduit should be rigid type and with threaded explosion-proof joints.
(4) Fittings should be of the explosion-proof type with five full threads or more in each hub. All covers should be treated with a compound to prevent corrosion. Screw-threaded flame paths give most reliable protection and require but little maintenance.

Flexible connections of explosion-proof construction are available for connecting to conduit systems, motors or equipment installed on moving bases.

Seals

All conduit runs should be sealed off in an approved manner:

(1) Where conduit terminates, immediately adjacent to an enclosure in which arcing or sparking occurs as at breakers, panel boards, branch circuits, motor starters, lighting units, switches, receptacles and similar devices.
(2) Wherever a conduit leads from a hazardous to a non-hazardous location such as between buildings.
(3) Within 2 feet of terminal and junction boxes to which rigid conduit runs, 4-inch size or larger are connected.

Seals should be located close to the housing in order to prevent a phenomenon known as "pressure piling." In long conduit runs it is considered good practice to install seals every 50 feet for this same reason.

In placing seals due consideration should be given to the probability of water being trapped. This water may be the result of condensation within the conduit system or it may have found its way in in some other manner. In some localities trapped water is a very real and troublesome problem.

Heretofore, water which collected on seals could not be removed, but now there is available a combination seal and drain which should be used if it is suspected that water may collect.

Water, if allowed to collect in various enclosures, eventually will cause electrical failures. To avoid this, explosion-proof drains are available which may be attached to the enclosures and thereby permit constant draining. This, in combination with explo-

sion-proof breathers, will effectually overcome many failures due to water or continued dampness.

Across-the-line motor starters must be designed for use in explosive atmospheres. Many types are available. The most commonly used type in hazardous areas is the combination type, from ⅛- to 100-horsepower. A circuit breaker should be installed

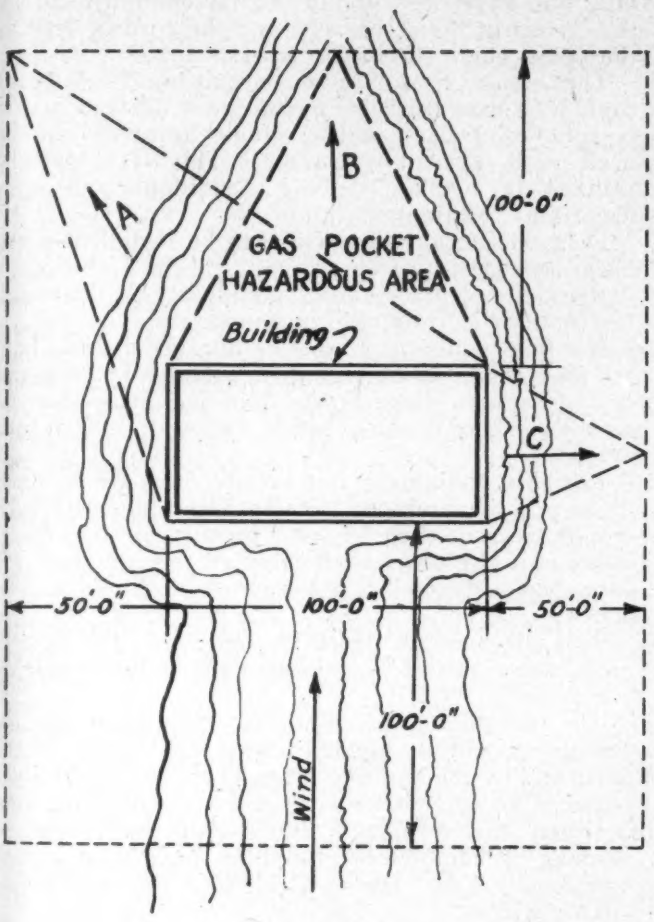

FIGURE 1
Gas of explosive mixture may be found in areas A, B, and C when wind is in that direction.

ahead of each starter to give short-circuit portection. The starter can be of the dry or oil immersed type. Care should be taken in making the proper selection as there are three points to consider.

(1) If corrosive chemicals are present and the equipment will be subjected to them. Oxidation can be eliminated by using oil-immersed starters in such areas.

(2) If condensation is the main source of trouble and corrosive chemicals are not present in sufficient quantities to attack the equipment, many engineers use dry-type enclosures equipped with breather valves and drains for the removal of the water and dampness that might accumulate in the bottom of the explosion-proof housing. Condensation is caused by temperature changes and the housing breathing at the cover joints.

(3) If corrosive chemicals and condensation are present many users install combination line starters of the oil-immersed type in suitable housings and equip the top of the housing with a breather valve and the bottom of the housing with a drain for the manual removal of water under the oil.

The drain and breather valve should be used as a combination to obtain maximum results. Drains are made in two designs: one for use with enclosures for oil-immersed devices, and the other when no oil is present. Both types may be useful in a single installation. The drains consist of non-ferrous bodies having threaded hubs and internal flame-tight (but not watertight) labyrinths. In the design intended for use where oil-immersed devices are employed, a valve is provided to prevent leakage of oil. Water, being heavier than oil, will accumulate in the bottom of the enclosure. Periodically, the valve can be opened and the water allowed to escape. When oil appears, the valve should be closed.

In the design intended for non-immersed devices, the water will escape continuously. If, because of dirt, the drainage labyrinth becomes clogged, it can be cleared by rotating the labyrinth member by means of the handle. A stop prevents complete removal of the labyrinth member.

Drains may be installed in explosion-proof devices by screwing them into a hub tapped for ½-inch conduit and having at least 5 threads which will engage at least 5 threads on the drain. Drilling and tapping walls of boxes and enclosures usually will not give 5-thread engagement required by the National Electric Code and Underwriters Laboratories.

Obviously, the drains should be installed at low points, also the end of the male hub should not protrude above the inner surface of the enclosure at its low point.

The appearance of mildew on electrical insulation is a sign that the insulation is under bacterial attack and unless the attack is arrested and the cause removed, insulation failure will result. Mildew is a bacterial growth promoted by continuously hot, damp atmosphere. Usually it is impractical to lower the ambient temperature but it may be practical to ventilate an enclosure and thereby obtain frequent changes of air.

Explosion-proof electrical enclosures cannot be vented in any of the usual ways because they must be kept flame tight. However, if they are equipped with explosion-proof drains and breather valves, condensed water can escape and a continuous change of air obtained. This effects a lowering of the temperature of the internal atmosphere. These results discourage mildew formation.

The breather valve is similar to the drain but is designed to be installed in the top of explosion-proof housings, allowing air to pass in or out as conditions vary. The labyrinth handle is a rotating cap to prevent dirt from interfering with the action of the valve.

Lighting switches should be of a type designed for use in explosive atmospheres. Lighting fixtures for 40, 60, 100, 150, 200, 300, and 500 watt are available.

Lighing fiixture conduits are made for use in hazardous locations where a broken lamp or an accidental ground or short circuit in the lamp receptacle or wires might cause an explosion with ordinary lighting fixtures. It is impossible to produce a lighting fixture which will permanently exclude a surrounding explosive gas, but the fixtures are constructed to prevent any explosion which may occur within the fixture from being communicated to the surrounding atmosphere. The castings and glass globes are strong enough to withstand any internal explosion and the threaded joints are tight enough to prevent escape of flame resulting from the explosion. The wiring compartment and lamp are separated by an explosion-proof threaded joint, which prevents an explosion that may occur in either compartment from being communicated to the other.

The National Electric Code requires that the globe of a lighting fixture in hazardous locations shall be protected by a guard when exposed to mechanical

injury. Fixtures are available with guards to comply with this requirement, and without guards for use where they are not exposed to mechanical injury.

Portable Hand Lamps

Explosion-proof and dust-tight hand lamps are constructed to provide the utmost safety, durability and ease of wiring. Non-sparking metals must be used. They have laminated plastic handles which provide a cool grip. The handle is firmly secured to the cast aluminum body, in which is mounted a keyless, composition lamp receptacle.

The cast aluminum globe holder (complete with clear, explosion-resisting globe) is threaded on the body and locked to prevent loosening by vibration. The guard is a combination of cast bronze rings and copper-clad wire bows. It is fastened to the globe holder by machine screws. For relamping, the globe holder, globe and guard are removed as a unit. Removing any screws is unnecessary.

Flexible Portable Cord for Hand Lamps

"Extra hard usage" three-conductor portable cord should be used with hand lamps. The third conductor or ground conductor should be concentrically wrapped around the two current carrying conuctors under the outer rubber covering of the cord to specify lamp cord for hand lamps. Two-conductor concentric cord with the third conductor marked with a green cotton covering should be requested.

Plugs and Receptacles

Circuit-breaking plugs and receptacles have proven their merit in ordinary industrial installations. There is very little burning and pitting of the contacts, even when used for breaking the circuit at full load. However, they are not suitable for use in hazardous locations. Realizing, however, there is a requirement for plugs and receptacles for use in hazardous locations, an explosion-proof, delayed-action circuit-breaking plug and receptacle has been produced. The purpose of the delayed action is to permit the arc to be broken before the arcing chambers are opened to the atmosphere.

The delayed-action explosion-proof plug and receptacle takes the place of an interlocking plug and explosion-proof switch, as specified in Article 500 of the National Electric Code. The delayed-action unit, however, has the following advantage—should the cord or cable be broken through undue strain, the plug will have been withdrawn far enough to break the circuit in the receptacle, and the cord is dead at the point where the break occurs.

The non-explosion-proof circuit-breaking plugs cannot be used with explosion-proof delayed action receptacles. Delayed-action plugs, however, can be used with regular receptacles. This fact may be utilized in a plant having hazardous and non-hazardous locations as follows:

Delayed action receptacles can be installed in the hazardous areas.

Regular receptacles of the same style and rating can be installed in non-hazardous areas.

Portable equipment suitable for use in the hazardous areas may be equipped with explosion-proof delayed-action plugs. Such equipment may then be used anywhere in the plant, including the hazardous areas.

Portable equipment not suitable for use in such areas may be equipped with regular plugs and such equipment can then be used in any non-hazardous location in the plant, with complete assurance that it cannot be connected to a receptacle in the hazardous areas.

This will prevent the inadvertent use in the hazardous areas of portable equipment that might cause an explosion.

The possibility of abnormal conditions in the conduit system is provided for by the strength of the parts and by the flame-resisting character of the joint between receptacle housing and conduit. The joint between the receptacle itself and the receptacle housing is completely closed by means of sealing compound. Pigtail leads provide for connection to the circuit wires.

In hazardous locations, Article 500 requires that frames of non-current-carrying metal parts of portable devices be grounded through an extra conductor in the portable cord. This not only protects the operator and carries leakage current to ground in case of insulation failure, but also drains off any static charges that otherwise might cause sparks. This device is intended for a 2-wire or 3-wire circuit but is provided with an extra pole for this grounding conductor. The grounding terminal in the receptacle is attached directly to the receptacle housing from which the ground circuit is completed through the conduit system or through a copper grounding wire, if necessary.

Of the remaining terminals in the plug and receptacle, one is identified white for connection to the identified or grounded conductor of the system, if such a conductor exists, and is brought to the receptacle.

Pressure Drop for Flow Through Beds of Granular Adsorbents

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PRESSURE drop data useful in the design and operation of industrial adsorption equipment have been determined from experimental studies on the flow of liquids and also of gas through various mesh sizes of activated bauxite and fuller's earth packed in a steel tower 6.065 inches in diameter and 10 feet high. A general relation based on a simplification of the mechanical energy balance and the so-called Fanning equation for friction, and plotted in the form of friction factor vs Reynolds Number, where

$$f = \frac{\Delta P\, D_p\, g_c\, \rho_{ave.}}{2\, G_o^2\, L}$$

and

$$Re = \frac{D_p\, G_o}{\mu}$$

all expressed in consistent units, is recommended for calculating pressure drop to within ±10 percent for a single fluid flowing through a standard grade of bauxite and fuller's earth of experimentally determined equivalent particle diameter.

A RECENT publication from the Research Laboratories of Porocel Corporation contained a wealth of new data on the drying characteristics of activated bauxite as an industrial adsorbent[1]. The increasing demand for almost complete moisture removal from many gases and liquids entering into newly developed catalytic processes is being met in an efficient manner by this low-cost, naturally occurring material of large effective surface area. Bauxite, and also fuller's earth, another natural material of large surface area, are being used in a variety of operations where it is necessary or desirable to remove small amounts of impurities from fluid streams. The decolorizing of lubricating stocks in petroleum refining[2], the clarifying of sugar solutions[3], and the desulfurizing[4] of catalytically reacted products have been described, showing the adsorptive capacity of these materials.

In most industrial applications of solid adsorbents it is usual practice to pass continuously the fluid to be purified through a packed column containing the adsorbent in granular form. For the design engineer, data on pressure drop or the resistance to flow offered by various mesh grades of the granular adsorbent are requisite in planning the type and size of equipment optimum for a particular adsorption process. Several studies of pressure drop through granular adsorbents have been reported, but in most cases the data have not been given in a form useful for design conditions other than those for which the tests were made. For example, some data show the resistance of an adsorbent to air flow[5], while results for another give the resistance to the flow of a particular organic liquid[6]. Since a general relation for pressure drop vs fluid flow based on pilot-plant-scale tests covering several fluids and several mesh grades of adsorbents has not been reported, it is believed that the data presented here will be of much value in many industrial operations where fluids pass through beds of such granular materials.

The basis for an analysis of pressure drop for isothermal fluid flow is an uniform duct between any two points, where there are no heat or work effects with the surroundings, is a combination of the mechanical energy balance, or Bernoulli's Theorem, and the so-called Fanning equation for energy loss due to friction[7].

$$-vdp = \frac{gdz}{g_c} + \frac{VdV}{g_c} + \frac{2fV^2dL}{Dg_c} \qquad (1)$$

For fluid flow through granular solids, an exact use of this equation is not possible without a knowledge of the actual linear velocity of the fluid through the interstices and the size of the flow channels. Such data are not easily obtainable. However, by assuming that the average linear velocity is proportional to the superficial velocity based on the overall cross section of the uniform bed, and that the average

NOMENCLATURE

- D — Diameter, feet
- D_p — Effective particle diameter, feet
- F — Friction, foot pounds per pound of flowing fluid
- F_e — Friction loss due to expansion
- F_c — Friction loss due to contraction
- f — Friction factor in Fanning equation, dimensionless
- G — Mass velocity, pound per (square feet) (second) pounds per square foot per second
- G_o — Superficial mass velocity, pound per (square feet of pounds per square foot of tower cross section per second)
- g — Local acceleration due to gravity
- g_c — Newton constant, (pound mass) (feet) per (pound force) (second^2)
- L — Length of packing, feet
- n — Number of particles
- ΔP — Pressure drop, pounds per square foot
- p — Pressure, pounds per square foot
- V — Linear velocity, feet per second
- V_o — Superficial linear velocity, feet per second
- v — Specific volume, cubic feet per pound
- W — Weight
- z — Height above datum, feet (potential energy)
- μ — Absolute viscosity, pound per (feet) (second) pounds per foot per second
- ρ — Density, pounds per cubic feet

particle size is an approximation for the average channel size, the equation can be modified to

$$-vdp = \frac{gdz}{g_c} + \frac{V_o dV_o}{g_c} + \frac{2fV_o^2 dL}{D_p g_c} \quad (2)$$

In addition to the friction between fluid and solids, there are probably numerous expansions and contractions of the fluid due to the irregular channel cross sections normal to flow. Energy loss due to a single expansion and single contraction can be calculated from the equations

$$F_e = \frac{(V_1 - V_2)^2}{2g_c} \quad (3)$$

$$F_c = \frac{K_c V_2}{2g_c} \quad (4)$$

To be theoretically consistent, some form of these equations should be included in equation (2). However, since actual velocities and actual areas normal to flow are not known, it will be assumed that losses due to expansions and contractions can be included in the constant f, i.e., the so-called friction factor f will be defined as an over-all energy-loss factor.

Exact integration of equation (2) is difficult. Under certain conditions approximate integration can be shown to give sufficiently accurate results. For liquids, or incompressible fluids, specific volume changes only slightly with pressure, and therefore linear velocity, V_o, remains practically constant. If changes in potential energy are corrected for in actual measurements of pressure drop, this term can be dropped along with that for kinetic energy. Then

$$-v\int dp = \frac{2fV_o^2}{D_p g_c}\int dL \quad (5)$$

$$\text{and } (p_1 - p_2)v_{ave} = \frac{2fV_o^2 L}{D_p g_c} \quad (6)$$

$$\text{or } \Delta P = \frac{2fV_o^2 L}{D_p g_c v_{ave}} = \frac{2fG_o^2 L}{D_p g_c \rho_{ave}} \quad (7)$$

For gas flow under conditions of temperature and pressure where the perfect gas laws may be used, and where a change in potential energy is negligible due to the low density of the gas, equation (2) can be simplified. Thus, dividing by v and substituting

$$v = \frac{RT}{p} \text{ gives}$$

$$\frac{-dp}{v} = \frac{-pdp}{RT} = \frac{V_o dV_o}{g_c v^2} + \frac{2fV_o^2 dL}{D_p g_c v^2} \quad (8)$$

$$\text{or } \int \frac{-pdp}{RT} = \frac{G_o}{2g_c}\int \frac{dv}{v} + \frac{2fG_o^2}{D_p g_c}\int dL \quad (9)$$

$$\text{and } \frac{p_1^2 - p_2^2}{2RT} = \frac{G_o^2}{2g_c} \ln \frac{V_1}{V_2} + \frac{2fG_o^2 L}{D_p g_c} \quad (10)$$

Since the relation of p vs v is practically linear, an arithmetic average of pressures can be taken as an average for v or $\frac{1}{\rho}$, i.e.,

$$\frac{p_1 + p_2}{2RT} = \rho_{ave}$$

Substituting this in the above equation gives

$$(p_1 - p_2)\rho_{ave} = \frac{G_o^2}{2g_c} \ln \frac{\rho_1}{\rho_2} + \frac{2fG_o^2 L}{D_p g_c} \quad (11)$$

$$\text{or } \Delta P = \frac{G_o^2}{2g_c} \ln \frac{\rho_1}{\rho_2} + \frac{2fG_o^2 L}{D_p g_c \rho_{ave}} \quad (12)$$

The first term on the right is negligible when $\frac{L}{D_p}$ is large and/or ΔP small. Therefore it can be dropped and the simplified equation is the same as that developed for liquids

$$\Delta P = \frac{2fG_o^2 L}{D_p g_c \rho_{ave}} \quad (7)$$

In studies of pressure drop for fluid flow through such materials as broken pumice, lead shot, uniform spherical and cylindral pellets, and a few other irregular solids, most writers [8, 9, 10, 11, 12] have correlated their data in the manner first introduced by Blake, i.e., by calculating the dimensionless friction factor f in equation (7) from experimental measurements of pressure drop, rate of flow, and particle size, and plotting this factor versus another dimensionless group composed of fluid viscosity, particle size, and

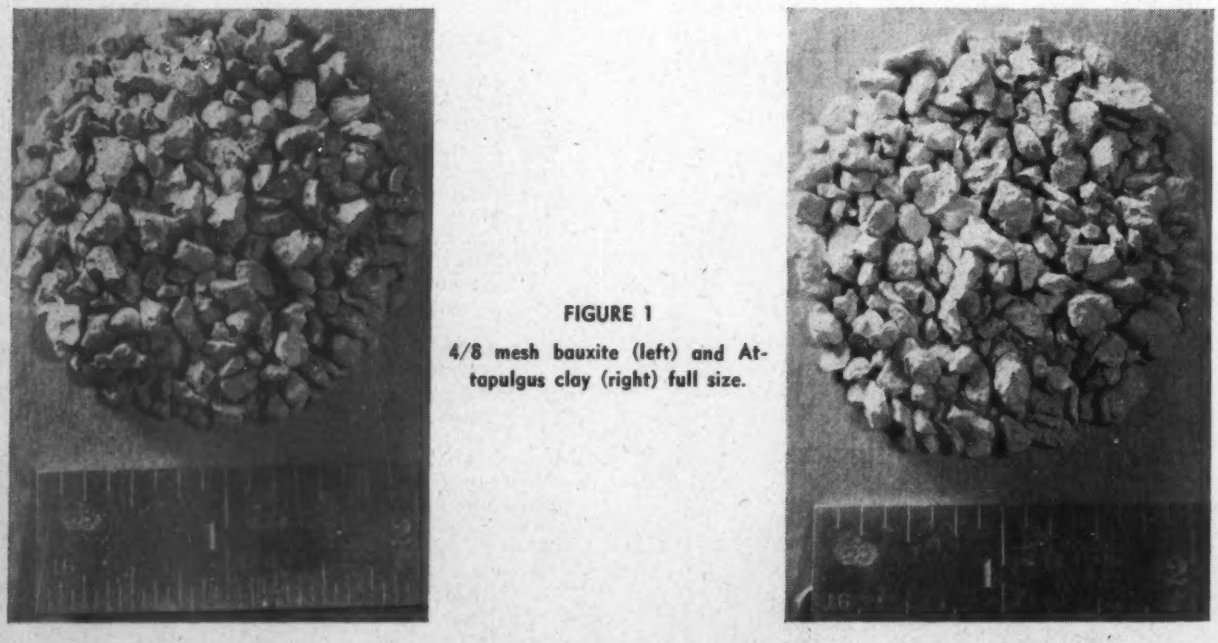

FIGURE 1

4/8 mesh bauxite (left) and Attapulgus clay (right) full size.

rate of flow, i.e., a modified Reynolds Number. The generally accepted plot of f vs Re for a single fluid flowing through beds of uniform solids is that of Chilton and Colburn[10] which shows experimental data correlated from several independent sources and covering a wide range of Reynolds number. However, it has been shown by other correlations [11, 12, 13] that such factors as particle shape, angularity, size distribution, and percentage void content in the bed should be considered in developing a general plot for use in predicting pressure drop. Obviously the term D_p, particle size, appearing in both the friction factor and Reynolds Number must include several variables definitive of a particular granular material; and to be of real value in a general correlation, this arbitrarily assigned dimension of length must be considered in light of its wide scope.

Standard Mesh Specifications

Commercial grades of granular activated bauxite and fuller's earth are both manufactured in much the same manner. After various processing operations, both materials are ground in roller mills and screened into several fractions meeting standard mesh specifications. In Figure 1 are shown typical standard grades. From these it can be seen that the granules of each material are most irregular, i.e., definitely not spherical, but yet more or less uniform with respect to themselves and of shapes characteristic of both bauxite and fuller's earth. Therefore it can be assumed that, other variables being the same, comparable grades of each material should fit one and the same correlation. However, since standard grades vary in range of particle size, i.e., a specification may call for a material passing No. 4 mesh and remaining on No. 8 mesh, or a material passing No. 20 and remaining on No. 60, such wide size distribution should be given effective weight in assigning an average particle size. Therefore in the handling of the experimental measurements of particle size in this work an effort has been made to relate an effective particle diameter to both the number of particles making up a sample and the average size as determined from a complete sieve analysis. The basis for this is the assumption that the specific gravity of all the particles of a particular grade is uniform, and that the weight of a given fraction, defined or limited by two consecutive Tyler standard sieves is proportional to the total volume times density, i.e.,

$$W = n \frac{\pi}{6} D^3 \rho \qquad (13)$$

where n is the number of particles and D is an equivalent spherical diameter equal to the arithmetic average of the width of the two sieve openings. Thus by a summation of terms in the form of equation (13) representing each fraction from a sieve analysis using sufficient standard sieves in consecutive order to include all particles, it can be shown that the effective particle diameter used hereafter in correlating all data is equal to the cube root of the total weight of sample divided by the total numbers of particles, or expressed in an equation

$$D_p = \sqrt[3]{\frac{\Sigma W}{\frac{W_1}{D_1^3} + \frac{W_2}{D_2^3} + \frac{W_3}{D_3^3} + \cdots \frac{W_n}{D_n^3}}} \qquad (14)$$

where the terms $\frac{W}{D^3}$ are proportional to the number of particles in each fraction.

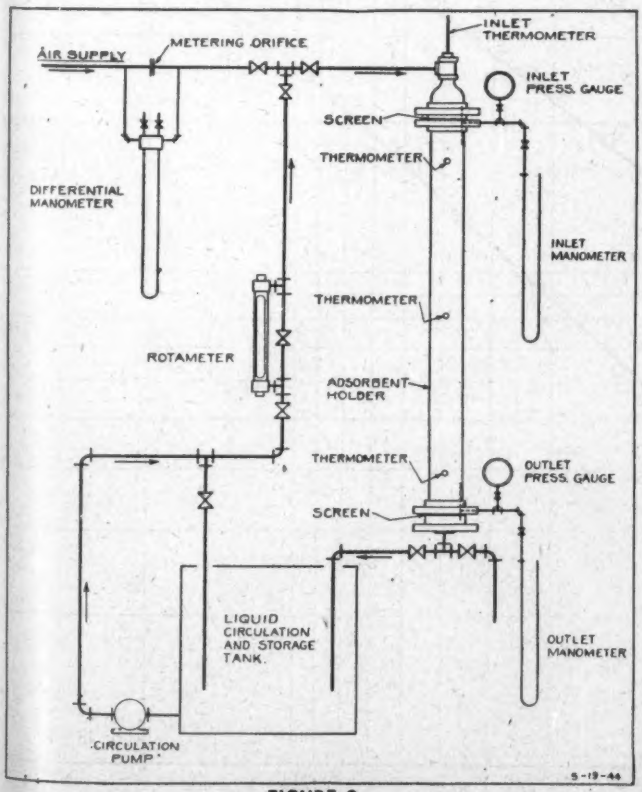

FIGURE 2

Apparatus used for the determination of the pressure drop through granular bauxite and fuller's earth.

Experimental Apparatus

In order to measure pressure drop and rate of flow in an experimental unit sufficiently large to make wall effect and end effects negligible, and therefore provide data suitable without correction to plant-scale equipment, a length of 6-inch standard steel pipe, fabricated to hold a 10-foot bed of granular packing between two supporting screens, was used for all tests. Approximately 115 pounds of activated bauxite or 62 pounds of fuller's earth were used in filling the 2-cubic-foot volume, thus giving beds sufficiently representative of a standard commercial grade. The packed column, set up vertically, was equipped with several pressure taps and a thermometer well. Piping was arranged to handle independently gas flow from a high-pressure line and liquid flow delivered by a circulating pump from a storage tank. Rate of gas flow through the column was measured by a standard sharp-edged orifice. Liquid flow was measured by a Fischer and Porter rotameter calibrated for each liquid used. Water and mercury manometers, and Bourdon gauges were used to measure the pressure drop across the packing in such a way that the resistance to flow due to the supporting screens was not included. All measurements were taken with the liquid or gas flowing from top to bottom through the bed. Where necessary, corrections were made for the fluid head in the column.

Samples of granular grades tested were:

Activated Bauxite	Fuller's Earth
4/8	4/8
8/14	8/14
10/20	14/20
20/60	30/60

Air at approximately atmospheric conditions was used for gas flow.

Liquids used were:	Sp. G. at 80° F.	Viscosity (Centipoises)
Stoddard Solvent (naphtha)	0.79	0.916
White Mineral Oil	0.83	8.05

A typical run consisted of filling the column with solids by means of a false-bottom stocking-like sack in such a way that degradation of the particles due to impact was avoided. Maximum bulk density of packing, i.e., lowest percentage of void content, was attained in each run by carefully tamping the outside of the column from bottom to top during the filling. The order of taking measurements was air flow first and then Stoddard solvent flow through the same bed. For mineral-oil flow through a bed already saturated with solvent, the column was drained overnight, dried by passing air through for several hours, and flushed thoroughly with the new liquid before measurements were taken. Viscosity and density determinations were made on the actual fluid being circulated through the system.

A sketch of the apparatus is shown in Figure 2.

The pressure-drop data for naphtha and gas flow through beds of activated bauxite are shown in Figures 3 and 4, respectively. The excellent agreement between the experimental results obtained in this work and published values is indicated in Figure 4.

Correlation of Data

Experimental data representing 17 separate runs were substituted in the equations

$$f = \frac{\Delta P\, D_p\, g_c \rho_{ave}}{2G_o^2 L}$$

$$Re = \frac{D_p G_o}{\mu}$$

to calculate values of friction factor and Reynolds Number. The correlation of these data, shown in Figure 5 as a plot of friction factor vs Reynolds number, gives a general relation for predicting pressure drop to within ±10 percent for the flow of a single fluid of known viscosity and density through a bed of standard grade activated bauxite or fuller's earth of experimentally determined equivalent particle diameter. Because the rate of fluid flow through beds of adsorbents usually is limited by the contact time necessary to maintain optimum adsorption, data were not obtained to extend the relation far into the so-called turbulent range. However, it is interesting to note that the over-all change from streamline to turbulent flow is a gradual one as might be suggested by the tortuous nature of fluid flow through irregular granular materials. The excellent correlation of data representing three fluids of differ-

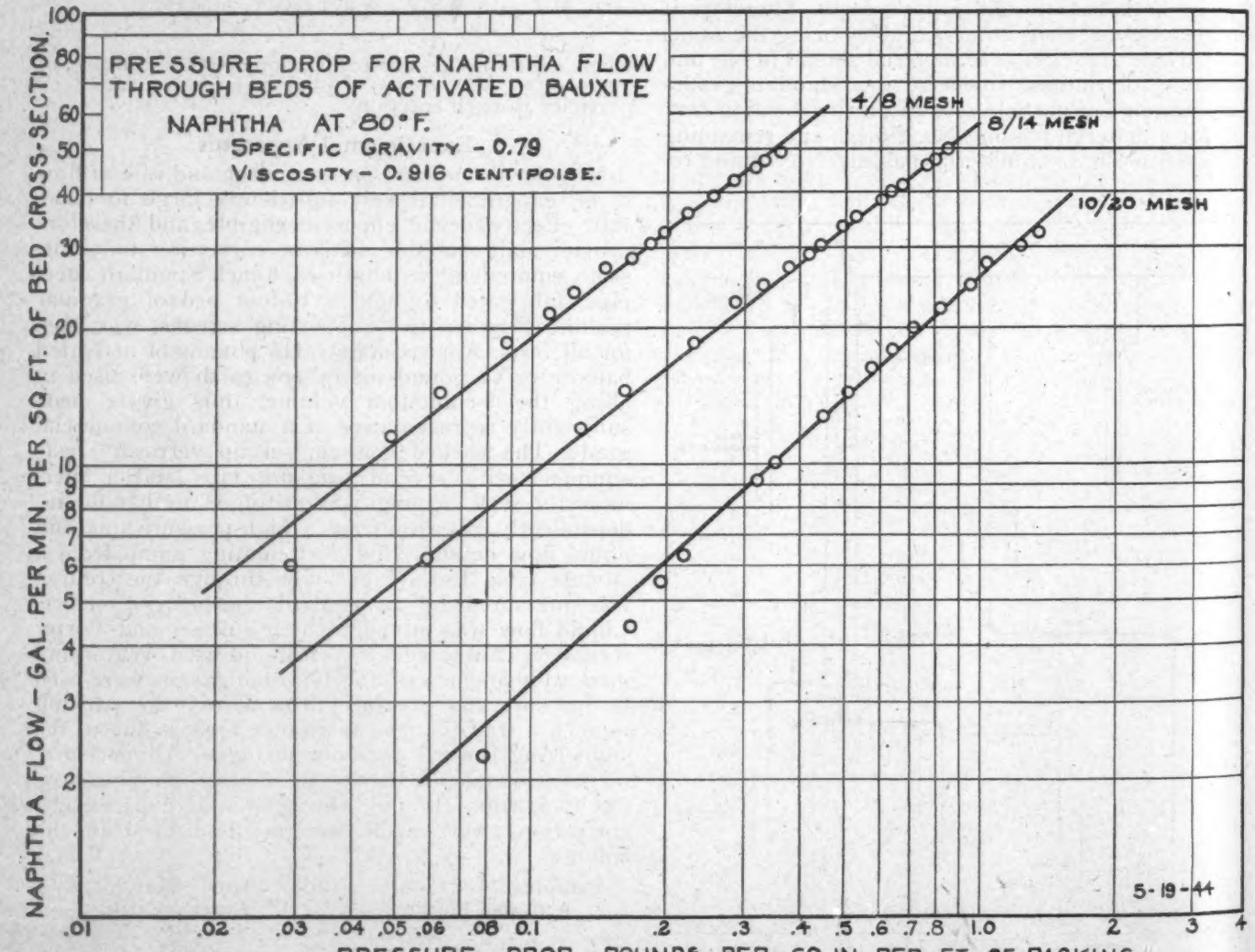

FIGURE 3

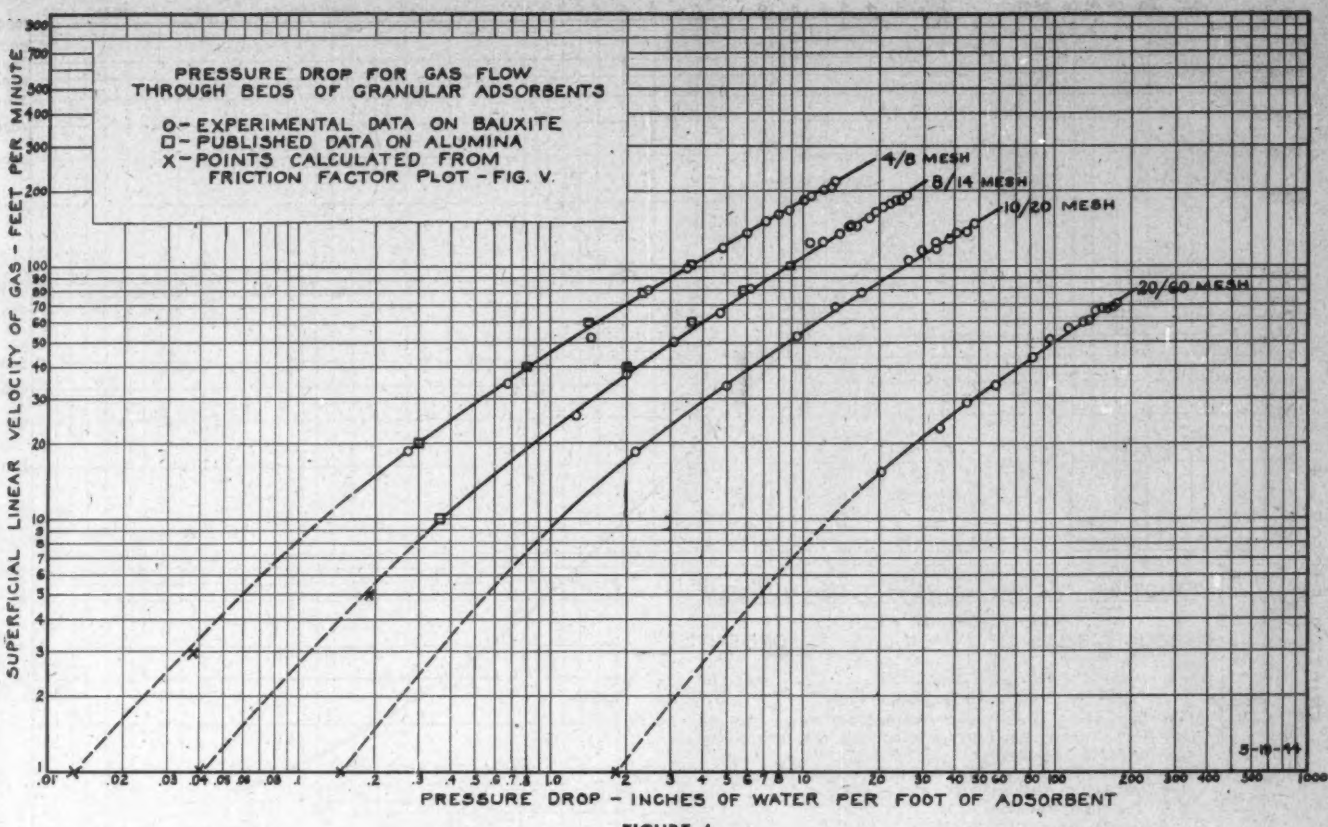
PRESSURE DROP FOR GAS FLOW
THROUGH BEDS OF GRANULAR ADSORBENTS
O- EXPERIMENTAL DATA ON BAUXITE
□- PUBLISHED DATA ON ALUMINA
X- POINTS CALCULATED FROM
FRICTION FACTOR PLOT - FIG. V.
4/8 MESH
8/14 MESH
10/20 MESH
20/60 MESH
SUPERFICIAL LINEAR VELOCITY OF GAS - FEET PER MINUTE
PRESSURE DROP - INCHES OF WATER PER FOOT OF ADSORBENT
5-19-44

FIGURE 4

ent viscosity and density confirms previously accepted uses of dimensional analysis for interpreting results. The only variable likely to introduce error in the use of these data for industrial equipment operating with any fluid is the degree of bed packing. Here it must be borne in mind that the correlation is based on lowest percentage void content. In practice it is not always expedient to obtain such conditions, but in any event the actual pressure drop will be less than that calculated.

It should be recalled that certain assumptions and simplifications have been made in the handling of calculations. Actually no error of any magnitude has been introduced with the present data, and therefore the relation between friction factor and Reynolds number can be considered accurate. However, in all cases it should be remembered that pressure drop is related to friction loss as shown in equation (2), i.e., by a differential equation combining the mechanical energy balance and the Fanning equation. Therefore, for considering a particular problem it would be well to start with equation (2) and make simplifications wherever applicable. This in no way limits the use of friction factor vs Reynolds number curve.

The treatment developed in this paper may be illustrated by considering, for example, a two-tower system filled with 4/8 mesh bauxite drying natural gas, chiefly methane, at 80° F. and 200 pounds per square inch line pressure. Assume that the superficial linear velocity of the gas through the adsorbent bed has been set at 30 feet per minute. The optimum rate must be based on a knowledge of the moisture content of the wet gas, the moisture content desired, and the dry gas capacity of the bauxite used[1]. For a preliminary calculation of pressure drop per foot of packing, assume that the perfect gas laws can be used for determining the gas density at the operating conditions.

Then

$$\rho = \left(\frac{16}{359}\right)\left(\frac{492}{540}\right)\left(\frac{214.7}{14.7}\right) = .594 \text{ lbs./cu. ft.}$$

Vis. of methane = .012 centipoise
V_o = 30 ft./min. = .5 ft./sec.
G_o = (.5) (.594) = .2970 lbs./(sq. ft.) (sec.)

$$Re = \frac{D_p G_o}{\mu} \quad \frac{(.11)\ (.2970)}{(12)\ (.012)\ (.000672)} = 338$$

From the curve, f = 8.3

Then $\frac{\Delta P}{L} = \frac{2fG_o^2}{D_p g_c \rho}$

$$= \frac{(2)\ (8.3)\ (.2970)^2 (12)}{(.11)\ (32.2)\ (.594)\ (144)}$$

$$= .058 \text{ lbs./sq in. per foot of bed.}$$

$$= \frac{(.0618)\ (29.9)\ (13.6)}{14.7} = 1.61 \text{ in. } H_2O/\text{ft. of bed.}$$

From this preliminary calculation it is evident that the change in gas density will be very small, since the pressure drop is small. Assume that the tower is packed 20 feet. Then the overall pressure drop will be

$$(20)\ (.058) = 1.16 \text{ lbs./sq. in. total}$$

For a more accurate calculation, the actual density of the wet gas at the operating conditions should be determined or calculated from data on hydrocarbons at high pressure, and then the average density to be used in the above calculations figured from the preliminary pressure drop determination.

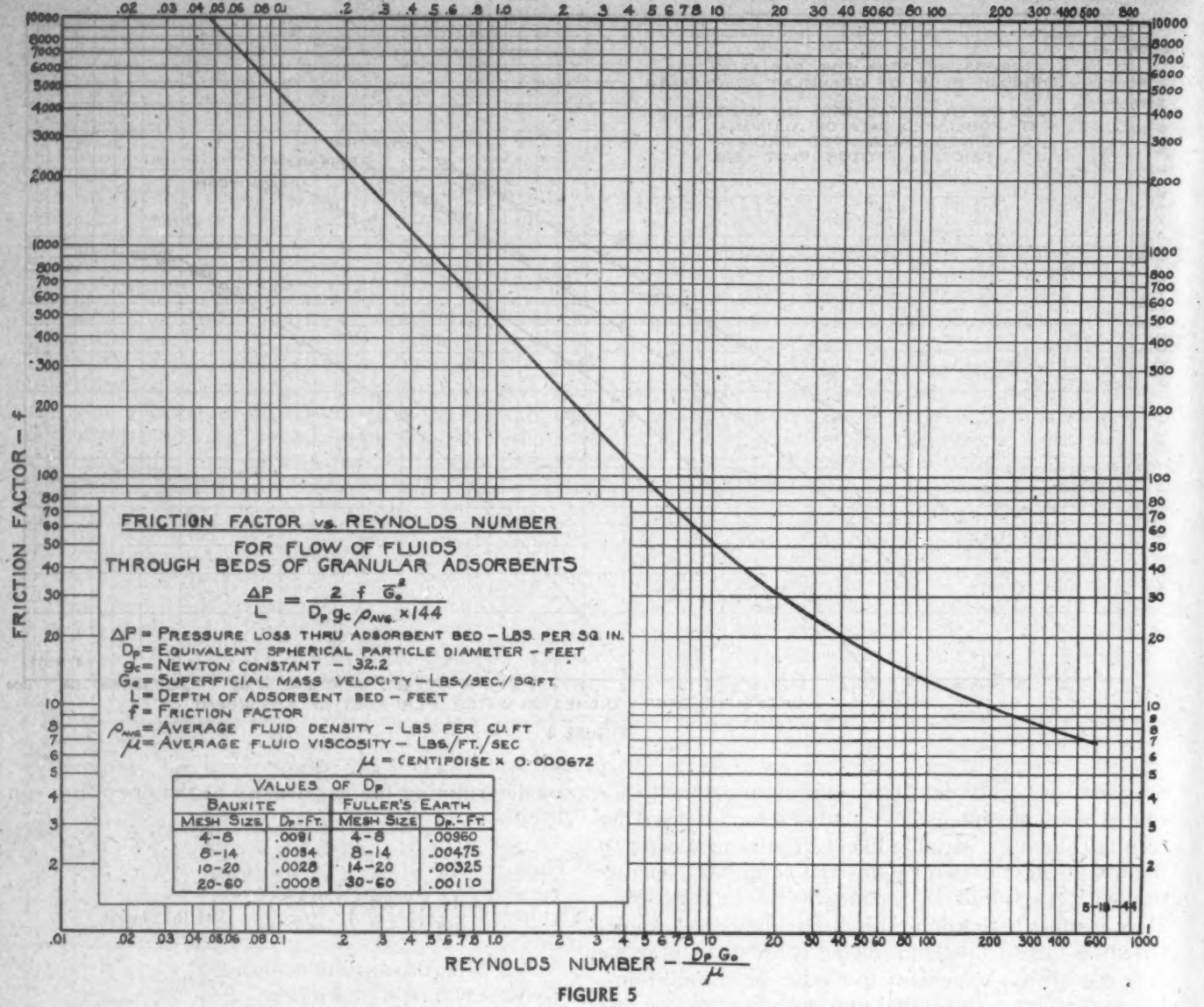
FRICTION FACTOR vs. REYNOLDS NUMBER
FOR FLOW OF FLUIDS
THROUGH BEDS OF GRANULAR ADSORBENTS
$\frac{\Delta P}{L} = \frac{2 f G_o^2}{D_p g_c \rho_{AVG} \times 144}$
ΔP = PRESSURE LOSS THRU ADSORBENT BED – LBS. PER SQ. IN.
D_p = EQUIVALENT SPHERICAL PARTICLE DIAMETER – FEET
g_c = NEWTON CONSTANT – 32.2
G_o = SUPERFICIAL MASS VELOCITY – LBS./SEC./SQ.FT.
L = DEPTH OF ADSORBENT BED – FEET
f = FRICTION FACTOR
ρ_{AVG} = AVERAGE FLUID DENSITY – LBS PER CU. FT.
μ = AVERAGE FLUID VISCOSITY – LBS./FT./SEC.
μ = CENTIPOISE × 0.000672
VALUES OF D_p
BAUXITE
MESH SIZE | D_p-FT.
4-8 | .0091
8-14 | .0054
10-20 | .0028
20-60 | .0008
FULLER'S EARTH
MESH SIZE | D_p-FT.
4-8 | .00960
8-14 | .00475
14-20 | .00325
30-60 | .00110
5-19-44
FRICTION FACTOR – f
REYNOLDS NUMBER – $\frac{D_p G_o}{\mu}$

FIGURE 5

Conclusion

The data presented in Figure 5 are useful for predicting pressure drop over a wide range of Reynolds Number. In the streamline range, the curve may be extrapolated indefinitely, since it has been established as a straight line. For high Reynolds Numbers, that is, in the case of gas flow at high pressure, care should be exercised in extrapolation. Pending further experimental data obtained from high-pressure work, it is recommended that a friction factor on the conservative or high side be taken for any extrapolation above a Reynolds Number of 500.

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What Takes Place In Polymerization

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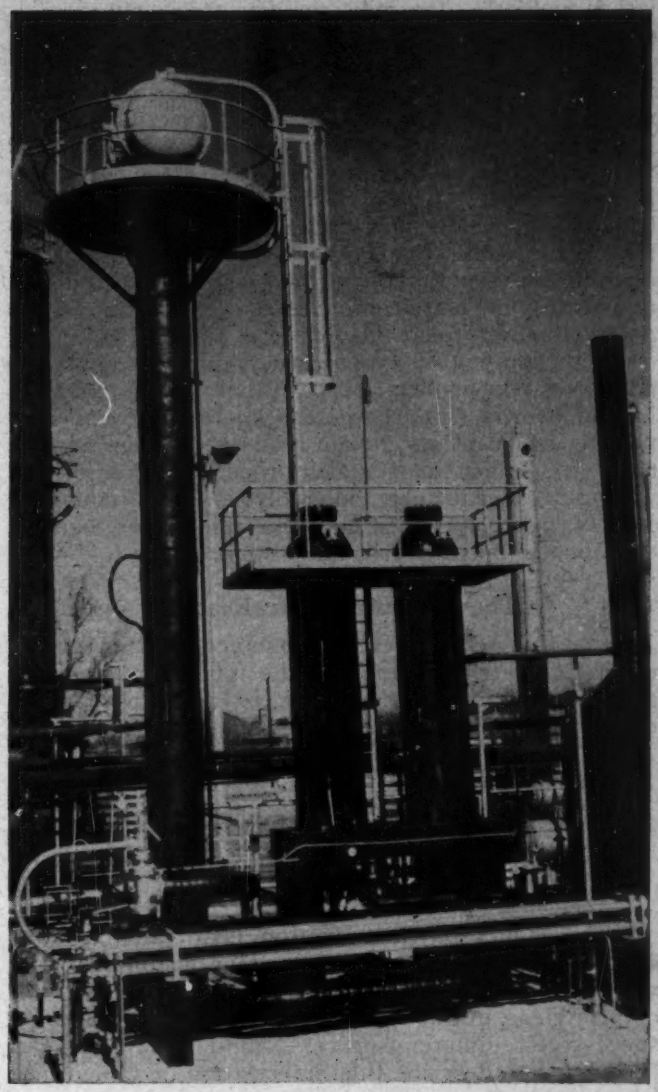


CRACKING and polymerization were the earliest to be developed and are the most widely used of all the chemical processes for gasoline manufacture. Both have increased the quality as well as the quantity of gasoline obtainable per barrel of crude oil. Cracking is essentially a molecule-splitting process. Polymerization, on the other hand, is a molecule-joining process. Polymerization unites gas molecules to form the larger molecules of gasoline. The reaction by which this synthesis occurs and the various means by which it is brought about in oil refineries are discussed in this article.

* * *

While *polymerization* actually refers to a type of chemical reaction, the refiner has applied the term specifically to a group of processes which employ the reaction in the conversion of cracked gases to gasoline. Some of these are classified below:

Thermal Polymerization Processes
- Unitary process
- Multiple coil process
- Gas reversion or polyforming

Catalytic Polymerization Processes
- "Solid phosphoric acid" process
- Sulfuric acid process
- Pyrophosphate process
- Clay process (Houdry)

In deciding which type of polymerization is to be preferred in a particular case, some factors which are of importance are: the nature of the available feed stock, the intended throughput of the plant, the importance of flexibility in operation, and the particular nature of the desired product. One cannot say that this process is more economical than that without reference to the particular situation for which it is intended. For this reason we shall consider the chemistry of polymerization in this article, and hope that the relative economics of the processes will become clearer as the processes themselves become so.

Some Important Terms

Because the reaction of polymerization had been familiar to the chemical profession long before its adoption by the oil industry, many terms are used in its description which have not been widely used by oil men. Some of these are defined here.

Monomer: The original polymerizing substance, contained in the "poly" plant's charge stock, is referred to as the monomer.

Dimer: When two monomer molecules are joined by the polymerization reaction, the product formed is called a dimer.

Dimerization: When the extent of polymerization is limited to the formation of dimer, the term dimerization is often used instead of polymerization.

Trimer: The product formed when three monomer molecules are polymerized together is called a trimer; the process, trimerization.

Polymer: If, as is the case with most commercial processes, the product contains dimer, trimer, and even

larger molecules, the indiscriminate term "polymer" is used.

Low and High Polymers: To distinguish between polymers whose molecules are made up of only a few monomer molecules, and those whose molecules contain hundreds or thousands of them, the terms "low polymer" and "high polymer" are used. Polymer gasoline is a low polymer while synthetic rubber and plastics are some high polymers now manufactured from petroleum derivatives. Certain fundamental differences justify the separate consideration of low and high polymerizations; and because the petroleum industry is concerned directly only with the former, this article is likewise so limited.

Interpolymer: (Also copolymer, codimer, etc.): While polymerization applies rigorously only to the union of like monomers, the charge stocks to all commercial polymerization plants contain a mixture of very similar monomers which may, under proper conditions, react with each other to form "interpolymers" or "codimers." In fact, interpolymerization is the rule rather than the exception in polymer-gasoline production.

The Polymerization Reaction

What happens when a substance polymerizes is described by the chemist in the form of a chemical reaction. Figure 1, for instance, is the chemical way[1] of saying that propylene can dimerize to give a "hexylene."

$$CH_3-CH=CH_2 + CH_2=CH-CH_3 \text{ ---- } CH_3-\overset{CH_3}{\overset{|}{C}}H-CH=CH-CH_3$$

FIGURE 1

The product of this reaction is a valuable constituent of gasoline while propylene is found in the waste gases from cracking. Hence, the dimerization of propylene might conceivably form the basis of a successful commercial process. Similar reactions can be written to describe the dimerization of some other hydrocarbons.

In no commercial process, however, is a single purified monomer charged to a polymer-gasoline plant. In some cases a separated fraction, containing for example just the four carbon hydrocarbons, is charged. However, the more usual practice is to take an entire refinery gas cut such as the stabilizer overhead of a cracking unit. In this case there are present several gases which may dimerize in a fashion analogous to that pictured in Figure 1. Further, the formation of codimers between any two of the different reacting gases must be considered. Each dimerization and codimerization reaction proceeds at its own pace (more precisely, its own "specific reaction rate"), competing for the available monomers until the period of reaction is terminated. But as the concentration of dimer builds up, there is an increasing tendency for the dimer molecules to combine with the remaining monomer in secondary reactions which likewise beget tertiary reactions and so on until polymers beyond the size range of gasoline molecules are produced. The reaction time must be limited to avoid excessive formation of this "heavy polymer."

What Will Polymerize

Having enjoyed a glimpse into the reactor of a polymerization plant, let us now turn our attention to the polymerization feed stock.

The paraffin hydrocarbons, which are found in natural, uncracked petroleum, do not polymerize under any condition. However, much of the paraffin content of petroleum is transformed by cracking into polymerizable substances, the "olefins." The chemistry of this useful conversion is based upon two general reaction types which are illustrated in Figure 2, for the case of ethylene formation.

$$CH_3-CH_3 \text{ ---- } CH_2=CH_2 + H_2$$

Dehydrogenation

$$CH_3-CH_2-CH_3 \text{ ---- } CH_2=CH_2 + CH_4$$

Splitting

FIGURE 2

Ethylene is the simplest member of the olefin class of compounds. All the gaseous olefins and corresponding paraffins that are found in significant amounts in polymerization charge stocks are classified, with their boiling points, in Figure 3.

OLEFINS	PARAFFINS
$CH_2=CH_2$ Ethylene (-155°F)	CH_3-CH_3 Ethane (-127°F)
$CH_2=CH-CH_3$ Propylene (-54°F)	$CH_3-CH_2-CH_3$ Propane (-48°F)
$CH_2=CH-CH_2-CH_3$ -butylene (23°F)	
	$CH_3-CH_2-CH_2-CH_3$ Normal butane (31°F)
$CH_3-CH=CH-CH_3$ -butylene (35 F)	
$CH_2=\overset{CH_3}{\overset{|}{C}}-CH_3$ Isobutylene (21°F)	$CH_3-\overset{CH_3}{\overset{|}{C}}H-CH_3$ Isobutane (14°F)

FIGURE 3

The distinctive feature of olefinic structure is evidently the "C=C" or "double bond" configuration, and many characteristic reactions of olefins arise directly from the influence of this bond. Such a reaction is polymerization.

The process of polymerization, originally designed to use up the by-product gases from cracking plants, has become so valuable a source of high-quality fuel that cracking is sometimes carried out solely to make polymerizable gases. In such a case natural gases are charged to the cracking coils instead of heavy oils, and the temperature employed is considerably higher—around 1300° F. This cracking process, ordinarily termed "gas pyrolysis," will be discussed in connection with thermal polymerization.

An alternate method by which olefins may be manufactured from natural gas is catalytic dehydrogenation. Because no splitting reactions (Figure 2) take place in this method, a much higher yield of

olefins may be obtained than would be possible by pyrolysis.

The polymerization of olefins is effected in processes differing so widely in operation that it is felt less confusing to present further remarks in connection with specific types of polymerization. The first type to be described comprises the thermal methods,[2,3,4,5] all of which, from the chemical point of view, are basically only modified cracking processes. Two of the catalytic methods are treated in some detail, the "solid-phosphoric-acid" method[5,6,7] and the sulfuric-acid method.[5,8] They are discussed separately because fundamentally different technical problems are encountered in the two widely distinct types of operation.

Thermal Polymerization

Customarily the term "thermal polymerization" is applied to any non-catalytic method by which liquid products are obtained from hydrocarbon gases. As a matter of fact, none of these methods is clear-cut polymerization as described in Figure 1, for at the high temperatures required for non-catalytic conversion of gases other reactions occur to a very significant extent. The gasoline from thermal polymerization contains, in addition to the olefinic polymers, naphthenic, aromatic, and paraffinic molecules. Some of the naphthenes, which are formed by cyclization of polymer molecures, are readily dehydrogenated to the corresponding aromatics. Aromatics may be produced also by a cyclic combination of further dehydrogenated monomer olefins. The hydrogen produced in aromatization reactions is free to hydrogenate olefinic polymers, yielding the corresponding paraffins.

By adjusting the conditions of the process, a certain reaction type may be favored over the others. High pressure favors polymerization while low pressure and a somewhat higher temperature favor dehydrogenation. Since dehydrogenation is chemically the most difficult step in the aromatization sequence, the conditions that favor dehydrogenation generally favor aromatization as well. For example, a process designed to produce olefinic gasoline operates at 950° to 1100° F. and over 1000 pounds pressure, while a process for manufacturing aromatics converts the same feed stock at 1200° to 1300° F. and less than 100 pounds pressure.

The temperatures involved in thermal conversions of olefinic gases are so high that one should expect some pyrolysis of the paraffins always present in polymerization feed stocks. The paraffinic gases do react, by splitting and dehydrogenation (Figure 2), to yield polymerizable olefins. By continually recycling the non-reacted paraffin gases a good yield of polymer may be obtained even from totally paraffinic charge. It must be emphasized, however, that polymer is formed much more readily from a highly olefinic charge stock than from one which is low in olefins. This is true not only because the initial presence of olefins precludes the need for a preliminary paraffin pyrolysis, but especially because olefins are innately more reactive than paraffins. Two of the paraffins, methane and ethane, are so resistant to thermal decomposition that they do not react at all under conditions met with in commercial processes. Obviously, these gases should be eliminated from recycle stock.

Aromatization and condensation reactions which lead to tar are favored by the high temperature required for effective cracking of paraffins as well as the extended time required for polymerization. For this reason tar formation presents a major problem in the design and operation of a process in which both splitting and polymerization occur simultaneously (the "Unitary Process"). If the conversion per pass is kept very low (which means a high recycle ratio in commercial operation) these condensation reactions may be stopped before large tar molecules are formed. Quenching at the furnace outlet also serves this purpose.

Control of the thermal polymerization reactions, and especially those involved in the formation of tar, is facilitated if a two-step process is used. A paraffinic charge stock is first submitted to a short, high-temperature, low-pressure pyrolysis step; then to a separately controlled, more extended polymerization step at suitably high pressure and somewhat lower temperature. If the feed contains olefins, it may be judicious to remove them by some kind of polymerization before the pyrolysis step, since their greater reactivity could result in extensive tar formation within the time necessary to obtain an economical conversion of paraffins. Different types of operation may be combined in such a "multiple coil" process to give the desired type of product.

The equipment used for thermal polymerization is similar to that employed in conventional cracking installations, although the more severe conditions encountered increase the initial cost of the polymerization plants.

A new technic permits the polymerization of a limited supply of olefinic gases without any separate polymerization unit. The gases are dissolved under high pressure in the charge to a reforming unit and converted simultaneously with the cracking of the reforming stock. This combination process, which takes advantage of the fact that conditions favorable to polymerization are employed in reforming, is called *polyforming* or *gas reversion*. Since reforming is not carried out at temperatures high enough for appreciable pyrolysis of paraffinic gases, the yield of polymer from the gases is restricted by their initial olefin content.

Catalytic Polymerization

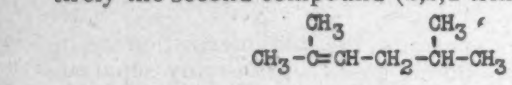
Under the influence of a suitable catalyst, the conditions required to effect polymerization of olefins are much less severe. A catalyst is a foreign material whose mere presence in contact with reacting substances is sufficient to increase their reactivity. This increase in reactivity is evidenced, in the case of the polymerization reaction, by a lowering of the temperature required to effect a given rate of reaction. Furthermore, the nature of the polymerization reaction is such that at the lower reactor temperature permitted by the catalyst, the pressure required to maintain a given yield is much less. A catalytic polymerization plant operating at 500° F. employs a pressure of 200 to 300 pounds, whereas a thermal polymerization plant, at 1000° F., requires over 1000 pounds pressure to yield comparable results.

The mechanism of the catalysed reaction appears to be fundamentally different. Ethylene, which is the most reactive olefin with respect to thermal polymerization, is the least reactive in catalytic processes. Of the other gaseous olefins, isobutylene is the most reactive, propylene is next, and the normal butylenes are least. Paraffinic gases, being unaffected by the polymerization catalysts, do not react at all

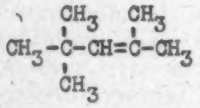
under the conditions encountered; they act only as diluents of the olefinic fraction of the feed.

The study of catalytic-polymerization reactions has been extensive because of the comparatively moderate conditions under which they may be carried out. For this reason, we know more about catalytic polymerization than we do about the apparently less complicated thermal reaction.

We can, for instance, predict exactly how two olefins are most likely to join each other, and consequently, what sort of product should be expected. As an example, consider the dimerization of isobutylene, which might conceivably result in, among others, any of the three dimers illustrated in Figure 4. However, experience tells us to expect almost entirely the second compound (2,2,4-trimethyl pentene).



2,5-dimethyl-2-hexene



2,4,4-trimethyl-2-pentene
"iso-octane"

FIGURE 4

A set of rules for predicting just what products are formed in any dimerization or codimerization has been drawn up by Wachter.[9] He points out that one must consider not only the different dimerization reactions, but also the possible structural rearrangements (isomerizations) of both monomer and dimer, in order to explain some products.

One may ask what difference it makes anyhow, which dimer predominates in the product. The answer is evident when the dimers formed from the same monomer by different reactions are compared, for they frequently differ widely in octane number. For instance, the octane numbers of those dimers illustrated in Figure 4, after hydrogenation to paraffins, (since data is not available for the olefins themselves) are 52, 100, and 103 respectively.

Although the predominating dimer from a particular monomer may not be the most valuable that could conceivably be formed, the tendency is for a high degree of branching, and therefore, a distinctly superior product. This explains the advantage in carrying out the sequence, cracking—polymerization—hydrogenation, to make a high-quality aviation blending stock. In Figure 5, for example, a series of reactions by which a normal octane molecule might be converted into a highly branched octane molecule is shown. Without any change in the size of the molecule, a very great improvement in the knock rating is obtained.

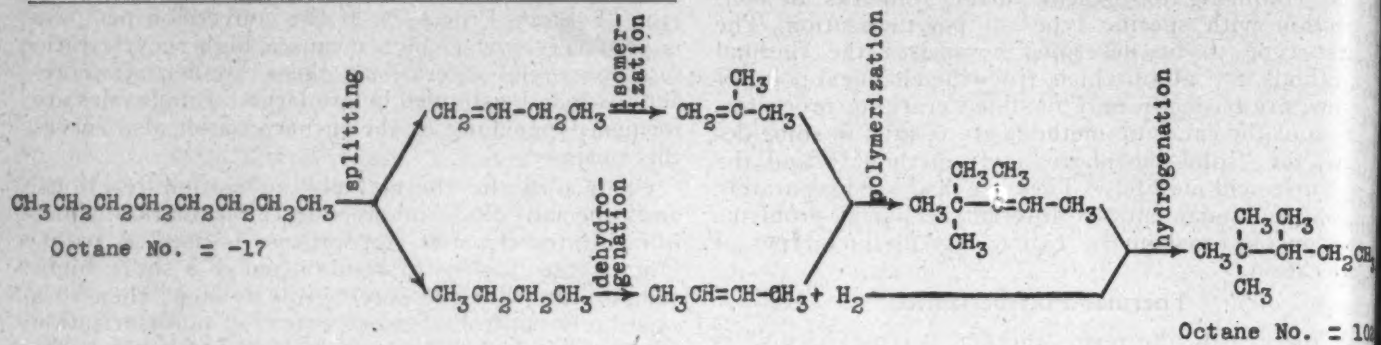


FIGURE 5

In connection with this diagram, it should be remarked that the first three steps, splitting, isomerization, and dehydrogenation, may all take place in one operation, that of catalytic cracking; and furthermore, that they may proceed in other sequences than the one indicated.

Hydrogenation

For blending in motor gasoline, the stabilized polymer may be suitable directly, or after redistillation, if excessive amounts of heavier polymers are present. However, the polymer must be hydrogenated before it will pass the gum specifications for aviation gasoline. Hydrogenation, which converts the olefinic polymer molecules to corresponding paraffins, is performed catalytically by various processes. A polymer of high quality and uniformity is manufactured especially for hydrogenation by the so-called "selective" methods of polymerization. The octane number of this polymer is raised from 85 to around 97 by hydrogenation. This may appear surprising to those who have come to associate olefins with higher octane ratings, but it is a fact that, among the most highly branched hydrocarbons, the presence of a double bond may actually decrease the octane rating.

Selective Polymerization

The selective methods charge a "B—B" (butanes and butylenes) cut which is obtained, by absorption or fractionation, from the refinery's cracked gases. The dimerization of isobutylene and the codimerization of isobutylene with normal butylene are brought about at conditions unfavorable toward dimerization of normal butylene. The latter reaction is not desired because it leads to a dimer of inferior octane rating.

The term "codimer" is often used for the specific codimer of isobutylene with normal butylene. Since this material is but slightly inferior to diisobutylene, and since twice as much codimer as diisobutylene can be made from a given amount of isobutylene(the supply of which is almost always a "bottleneck"), the attempt is usually made to induce as much interpolymerization as possible. Interpolymerization is favored by a high ratio of normal butylene to isobutylene in the reacting mixture, and this may be obtained by recycling the spent gases and by maintaining a concentration of absorbed normal butylene in the catalyst.

Heat of Reaction

Although energy is required to induce polymerization, the energy given off as the reaction takes place more than compensates for it. This *heat of reaction*

is hardly noticeable in the high-temperature thermal methods, but it is a most important factor in catalytic methods.

Heat of the reaction may increase the temperature in the reactor of a catalytic plant far beyond its optimum value, so some means for removing excess heat is required. The methods of heat removal in commercial practice include dilution of the feed by inert materials, such as recycled paraffinic gases; admission of an inert cooling fluid directly into the reactor; and circulation of a cooling fluid through or around the reactor in coils or jackets. Good temperature control in the jacketed type reactor may be obtained by maintaining such a pressure on the jacket that the coolant boils at the temperature desired, thus absorbing heat with no change in temperature. The heat that is removed may be utilized to any extent considered practical—to preheat the feed to the reactor, for example.

Sulfur

An appreciable quantity of hydrogen sulfide (H_2S) is usually present in polymerization feeds. Under the influence of the catalysts, this substance reacts with olefins to form mercaptans, according to reactions of the type illustrated in Figure 6.

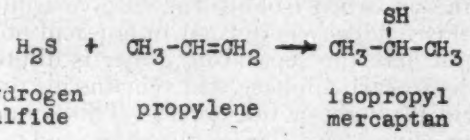


FIGURE 6

Since mercaptans affect the lead susceptibility of gasoline most adversely, their elimination is desirable. And since removal of hydrogen sulfide from gases is far simpler than removal of mercaptans from gasoline, the feed stock is treated before polymerization. Several methods based on reversible absorption in an alkaline solution are available for the removal of hydrogen sulfide from a gas stream.

"Solid-Phosphoric-Acid" Polymerization

Polymerization by the "solid-phosphoric-acid" method is carried out at about 450° F. and at 200 to 500 pounds pressure. Under these conditions, polymerization of propylene and of the butylenes is practically complete, while almost three fourths of the ethylene remains unreacted. As the temperature is raised, within limits set by the catalyst, the yield of polymer increases, while the octane number tends to decrease. This is principally because those monomers which react more extensively at the lower temperatures are the ones which yield the more desirable polymers.

The product from solid-phosphoric-acid polymerization consists primarily of those dimers and trimers which would be predicted if only the type of reaction pictures in Figure 1 were to occur. Also, however, significant amounts of naphthenes, aromatics, and paraffins are formed as the result of such secondary reactions as cyclization, aromatization, and hydrogenation. The same sort of thing goes on more extensively in thermal polymerization, and the reactions were discussed earlier in that connection. There is[10] a propitious inclination of the least valuable polymers toward aromatization, and of the most valuable, toward hydrogenation; both reactions which tend to increase the final octane number of the product.

The conditions for selective operation with phosphoric-acid catalyst are a temperature maximum of around 340° F., at 600 to 700 pounds pressure, The feed must be preheated to somewhat above 260° F. to obtain a sufficient rate of reaction, as well as to prevent damage to the catalyst from excessive hydration. The permissible temperature rise, then, is comparatively small and proper heat removal is most important. In the selective method, cyclization and aromatization reactions are of negligible importance, and the product is essentially a mixture of dimer with perhaps 10 to 20 percent of trimer.

The catalyst in this process is phosphoric acid (H_3PO_4) which has been impregnated into a pelleted "carrier" of inert material. In a typical installation, the catalyst is contained in vertical bundles of tubes surrounded by a cooling medium; an arrangement resembling a large heat exchanger. There are usually several individual reactors so that one can be bypassed for regeneration or refilling without stopping the operation completely.

Regeneration may become necessary from time to time for the removal of a deposit of carbonaceous material that accumulates on the catalyst and gradually impairs its activity.

During the high-temperature regeneration step, the phosphoric acid is dehydrated to an inactive form by the reaction shown in Figure 7.

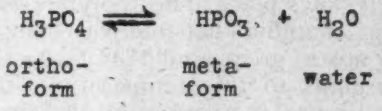


FIGURE 7

This reaction may be reversed by blowing the catalyst with steam for a few hours, after which the catalyst has regained its activity. Throughout the on-steam period, inclusion of a few percent of steam with the feed gases curbs any tendency toward dehydration of the acid, provided the reactor is not allowed to overheat. On the other hand, if the temperature drops too low, excessive hydration may lead to physical collapse of the carrier. This becomes important only in selective operation where the catalyst temperature may be as low as 260° F. and the water content of the feed must be limited carefully.

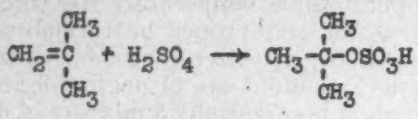
There is another process,[11] very similar to this in design and conditions of operation, which substitutes copper pyrophosphate ($Cu_2P_2O_7$) for phosphoric acid. An interesting practice in this method is to control the temperature in the reactor by spraying liquid recycle over stacked beds of catalyst.

Sulfuric-Acid Polymerization

Despite the marked chemical similarity between sulfuric-acid polymerization and phosphoric-acid polymerization, the commercial processes employing these catalysts have very little in common. The sulfuric-acid methods charge a *liquefied* hydrocarbon fraction (containing the butylenes and butanes), and contact it with a *solution* of sulfuric acid. The acid is continuously recirculated, and make-up acid is added to maintain an effective strength of around 70 percent. The flow might be compared with that of an acid-treating plant.

The original sulfuric acid method, "cold-acid polymerization" is a two-step process for synthesizing di-

isobutylene. The first step, absorption of isobutylene by the acid phase, is brought about by a chemical reaction between isobutylene and the acid which yields an acid-soluble product. For qualitative understanding of the process this reaction may be considered to proceed as described in Figure 8, although the absorbed isobutylene is assumed[12] to exist predominantly in the form of an "alcoxonium" ion ($C_4H_9OH^+_2$).

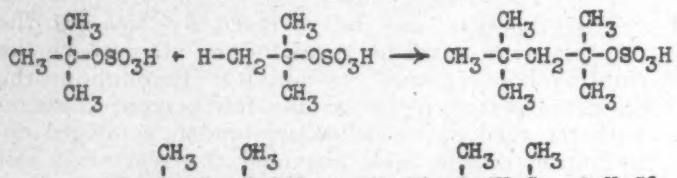


Absorbtion

FIGURE 8

By the use of two countercurrent absorption stages, about 90 percent of the isobutylene may be absorbed without appreciable absorption of the hydrocarbons. Because of the rather large evolution of heat in the absorption reaction, refrigeration is required in order to keep within the optimum temperature range, around 75° to 100° F. At the higher temperatures the *rate* of absorption is greater, but the possible *degree* of absorption is less and this is the limiting factor in practice.

"Selection" of the isobutylene is effected when, following absorption, the acid phase is allowed to settle out and is separated. This acid mixture is charged to the second step in the process, where the polymerization itself takes place. The "polymerizer" is simply a reaction chamber capable of being uniformly heated, by steam, to around 210° F. As the acid mixture is brought to this temperature, the reactions shown in Figure 9 occur, and the product, diisobutylene, is removed as a separate phase.



Dimerization

FIGURE 9

Diisobutylene is hydrogenated to "iso-octane," which has an octane rating of 100 and sufficiently low gum-forming tendencies that it is suitable for use in aviation fuels. When the hydrogenated codimer of isobutylene and normal butylene was observed to be only slightly inferior to pure iso-octane in antiknock tendencies, a possibility of doubling the yield from a given quantity of B-B feed without materially affecting the quality led to the development of the hot-acid process. Except for special purposes, this method has completely supplanted the earlier type.

The term "hot acid" is used because of the higher temperature, 170° to 200° F., at which the feed is contacted with acid. At this temperature the absorption is no longer selective, for both normal and isobutylene are absorbed. Furthermore, the absorbed butylenes *co*dimerize immediately, precluding the need for a subsequent polymerizer. But why are not the respective dimers of normal and isobutylene formed, as well as their codimer? The answer, in the case of normal butylene, is simply that this reaction requires a higher temperature than that maintained in the process. In the case of isobutylene, however, we must resort to a different explanation, for isobutylene actually forms its dimer somewhat more readily than codimer. This explanation depends on the fact that a *relatively* high concentration of absorbed normal butylene is built up; this is to be expected in view of the fact that normal butylene is almost invariably present in excess in B-B feeds. Although newly absorbed isobutylene molecules would prefer, shall we say, to pair up with other isobutylenes, the normal butylenes are so much more plentiful that few isobutylenes succeed in holding out long enough.

There are some interesting points of comparison between cold-, and hot-acid polymerization. In the earlier method, there is a maximum extent of absorption, a "saturation" effect, which may mean that 10 percent of the isobutylene cannot possibly be absorbed under the conditions prevailing in the commercial process. Such a limit is not even approached in the hot-acid plant, because the isobutylene reacts as quickly as it is absorbed.

Another problem arising in the cold-acid process is trimer formation. As the dimer separates out in the polymerizer section it remains, for a time, in contact with the acid phase. In this period, some of it is reabsorbed by the acid, whereupon it may react with the absorbed isobutylene to give trimer. To be sure, this tendency is present in hot-acid polymerization, but here the separating dimer is diluted by the large hydrocarbon phase that remains in contact with the acid throughout the process. This dilution tends to keep dimer away from the acid, and a 10 to 15 percent decrease in trimer formation results.

In either sulfuric acid process, some dissolved and entrained acid and alkyl sulfates remain in the product. A simple caustic wash suffices to remove the free acid, although the sulfates must be first hydrolyzed, by heating with steam, to "break loose" the acid.

In conclusion, it might be suggested that the mechanism of acid catalysis described by Figures 8 and 9 is applicable to the hot-acid method, and the phosphoric acid method (if phosphoric acid is substituted for sulfuric acid in the reactions). It is well to bear in mind, however, that this scheme is but a convenient simplification. Under various conditions the nature of the reactions may change, and several different mechanisms have been postulated[13,14,15,16] for particular situations.

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Chemicals from Petroleum

An extract from the paper of H. D. Wilde, Humble Oil & Refining Company, before the regional meeting of the American Institute of Mining and Metallurgical Engineers, Houston, May 8, 9 and 10, 1944

THE outstanding raw material used today for synthetic chemical production, especially from a volume standpoint, is butylene. It is an olefin having a chemical formula C_4H_8 and exists in two forms depending upon the arrangement of the carbon and hydrogen atoms in the molecule. If the carbon atoms are arranged in a straight-chain structure it is called "normal butylene" and if arranged in a branched chain it is called "isobutylene." In many respects these two forms are similar but differ enough in specific chemical and physical properties to be different compounds and to be used for different purposes. Of the two, isobutylene is considerably more reactive. The principal source of butylene is the cracking operation carried on in refineries and may be one of the older thermal type of processes or one of the newer catalytic-cracking processes. Catalytic cracking has become the preferred source because of the greater yield of butylenes that can be obtained by this process. The butylenes are produced in conjunction with other products from the process and are, of course, not the whole products but many of the catalytic-cracking units have been installed during the last few years primarily to provide butylenes needed for the 100-octane gasoline and the synthetic-rubber programs. Cracking is not the only source of butylene since some normal butylene is also produced by a process in which hydrogen is removed from normal butane through the use of a suitable catalyst. When this method is used the operation is carried on exclusively for the production of butylenes as there are no other products of importance from this operation.

In the 100-octane gasoline program both normal and isobutylene are used for making aviation alyklate and hydrocodimer. Butylene alkylate, the backbone of the 100-octane gasoline program, is made by combining either normal butylene, sobutylene or a mixture of the two with isobutane. In common with a great majority of chemical syntheses, the presence of a suitable catalyst is necessary for the reaction to take place. The product obtained from the union of butylenes with isobutane is called "alkylate" and after purification by distillation is ready for use as a high-octane component in 100-octane gasoline. If a mixture of normal butylene and isobutylene is placed in contact with an appropriate catalyst the isobutylene will unite with the normal butylene to form what is known as "codimer." This codimer is subsequently converted to hydrocodimer by hydrogenation in which form it is a high-octane component suitable for use in 100-octane gasoline. Both alkylate and hydrocodimer are products that are essential in the manufacture of 100-octane gasoline because of their octane rating and because they possess the proper boiling range.

Alkylate and hydrocodimer are generally not classified as synthetic chemicals because they usually are blended into 100-octane gasoline as the end product at the place where they are produced and because in the past they have not been made by chemical companies and marketed as chemical products. They have, nevertheless, as much right to be called synthetic chemicals as ethyl alcohol or acetic acid. Security regulations do not permit disclosure of the rate at which these products are made but it can be stated that never in history have synthetic organic chemicals been made on the scale that these components of the 100-octane gasoline are being made today.

Normal butylene is of primary importance in the synthetic-rubber program since it will be used in making two thirds of the butadiene required for the GR-S type of synthetic rubber, the other third being made from grain alcohol. The program calls for a total synthetic-rubber production of 850,000 long tons (950,000 short tons) per year, and butadiene production is scheduled at the rate of 690,000 short tons per year. Thus on a tonnage basis, butadiene from petroleum is equal to 48.5 percent of the total program.

The chemical formula for butadiene is C_4H_6 which differs from that of butylene, C_4H_8, having two less hydrogen atoms in the molecule. By removing two hydrogen atoms from a molecule of butylene employing a process of catalytic dehydrogenation, butylene is converted to butadiene. Only normal butylene, with the four carbon atoms in a straight chain, will serve for this conversion, since in butadiene the four carbon atoms are also arranged in a straight chain. In cracking operations normal butylene is always produced in admixture with isobutylene and hence one of the essential steps in the manufacture of butadiene is the removal of the isobutylene from the mixture. This is accomplished by a chemical process that depends upon the greater chemical reactivity of the isobutylene. The product obtained in this process can be and generally is converted into a high-octane blending agent.

The isobutylene removed from the mixture is the source of the raw material used in the manufacture of butyl rubber. Inasmuch as butyl rubber is the result of combining isobutylene with lesser quantities of isoprene, both of which are obtained from petroleum, butyl rubber is a product derived entirely from petroleum.

The Synthesis of Lubricants from the Fischer-Tropsch Process

PART 1

F. FISCHER and H. KOCH

(Translated from "Brennst.-Chemie," Vol. 14, P. 463-468)

As IS well known, the Fischer and Tropsch process for synthesizing petroleum from carbon monoxide and hydrogen furnishes gaseous, liquid, and solid hydrocarbons which are composed almost exclusively of hydrocarbons in the paraffin and olefine series.[1] The main product of this reaction is a mixture of liquid hydrocarbons which by distillation, furnishes motor fuel designated as kogasin I and a gasoil fraction, kogasin II. The residue obtained in this distillation is primarily solid paraffin wax. Nowhere in the distillaton of the original raw material are fractions obtained which have viscosity or which can be classified as lubricants similar to petroleum lubricants. This fact is easily explained by the composition of the raw material since it is composed of hydrocarbons almost exclusively of open chain.

Aromatic or ring compounds or naphthenic hydrocarbons are entirely lacking in the raw synthetic material. Even though the constitution of lubricants has not been quite definitely established as yet, it is known that ring compounds which are more or less alkylated are necessary in order to have hydrocarbons possess the property of viscosity and lubricant-film formation.

It has not been possible to alter conditions of the Fischer and Tropsch process so as to make motor fuels and at the same time obtain hydrocarbons containing ring compounds instead of hydrocarbons composed entirely of open chains. It would be highly significant, nevertheless, to obtain good lubricating oils in the synthesis besides manufacturing motor fuel. We have therefore recently started development work in order to prove whether kogasin, as raw material, could be converted to valuable lubricating oil. We have been rewarded in this objective in being able to produce lubricants which are quite similar to petroleum oils by using the synthetic gasoil called kogasin II. Even though these experiments are only first-stage developments, we wish to report the results of this work and to bring the knowledge on this subject up to date.

To begin with, we sought the many methods reported in the literature on synthetic lubricants and carried out some of the procedures, which are reportedly based on the chemical constitution of petroleum lubricants. Literature references concerning the constitution of lubricating oils are not as numerous or as explanatory as might be expected.[2] These references bring out that the properties of lubricants are very much dependent on the type of crude oil in question. In general, two types of oils are mentioned, namely, the paraffin-base oils and the naphthene-base oils (asphalt type). Between these two series of oils are the so-called mixed-base oils.

The so-called paraffin-base crudes yield lubricants known as paraffinic oils, but which, according to the latest researches, actually consist of hydrocarbons with naphthenic rings containing alkyl side chains, or the rings are joined by aliphatic chains.

The corresponding products from naphthenic and mixed-base crude oils contain more aromatics and naphthenic-ring hydrocarbons. The nature of the crude determines the temperature susceptibility or viscosity slope of the lubricants, which in the case of high grade oils is found to be very low. From this standpoint the paraffinic lubricants such as those of Pennsylvania type, are therefore classed as valuable products while those from asphalt-base oils, with their greater temperature susceptibility, command a lower price as far as lubricants are concerned.

As to the molecular weights of the lubricant hydrocarbons, it can be said that they are in the range of 400-500, with the ultimate analysis of these materials showing about 86.5-87.5 percent carbon and 13.5-12.5 percent hydrogen.[3]

From this very short literature survey it will be understood that it is necessary to proceed with some process to combine or connect up the purely paraffinic hydrocarbons with some type of ring compounds in order to arrive at the formation of viscous oils; this is necessary if one is compelled to use pure paraffinic material as raw material. This problem was solved and reported in the literature by other workers in this field in producing synthetic lubricants from similar raw materials. Therefore, we desire to describe our particular procedure in this communication wherein we were able to obtain synthetic oils of very high quality.

As to literature references, it is not intended to report here an exhaustive review on the subject since very recent workers in this field have brought the material together in a systematic manner.[4]

Literature Review

In general, the olefine hydrocarbons have been used to the greatest degree as raw material in all types of synthesis—both gaseous and liquid olefines being combined with other hydrocarbons. It is well known that the olefines are excellent starting materials for many reactions and easily undergo polymerization and condensation reactions. As aids in the polymerization of these materials several polymer

izers are available—for instance, the use of ultraviolet light, electrical energy (static), heat, pressure, and catalysts. The three last agencies have been employed to the greatest extent.

The earliest observations along these lines in the case of olefine reactions were made many years ago. For instance, the action of sulphuric acid on gaseous and liquid olefines had been observed in the early work of Butlerow,[5] who has spent many years in the synthesis of lubricants. Guiselin[6] had proposed treating olefine-rich fractions from cracked gasoline with sulphuric acid in order to obtain viscous or polymerized oils. The anhydrous metallic chlorides, such as those of aluminum, iron, and zinc, as well as the gaseous boron fluoride, are exceedingly powerful catalysts as has been shown very recently.

Lately, Nash, Stanley and Bowen[7] occupied themselves with the utilization of ethylene, polymerizing it to lubricating oils. This work with ethylene had originated earlier with Otto[8] who showed that ethylene gave good yields of lubricating-oil hydrocarbons when treated under pressure with boron fluoride as a catalyst.

According to Nash and his co-workers, such lubricants, however, did not compare favorably with the petroleum oils when they were evaluated as to their viscosity-temperature relationships, and their resistance to oxidation in the presence of oxygen. Much better oils and a high type of lubricant were obtained and described in the procedures used by Sullivan, Voorhees, Neely, and Shankland.[9] According to the reports of these authors, it is possible to obtain synthetic lubricants which equal the best oils obtainable from crude petroleum by a procedure which consists of first cracking paraffinic petroleum fractions, followed by polymerization of such cracked distillate with anhydrous aluminum chloride.

In order similarly to convert paraffin hydrocarbons which are relatively plentiful, investigators in this field have sought to introduce reactive substituents into certain positions of the hydrocarbon molecule. To make the paraffin hydrocarbons reactive the simplest way, of course, has been to split the molecule, forming material containing double bonds, as occurs on a large scale in the so-called cracking process. The introduction of halogens into the paraffin molecule also makes the resulting hydrocarbon susceptible to many reactions; for example, the splitting off of hydrogen halide, a form of dehydrogenation results in polymerization and condensation reactions with similar hydrocarbon material, or the halide material may also enter easily into reactions with hydrocarbons of other series.

Zeller and Gmelin[10] first proposed reactions of this sort in experiments where low-viscosity mineral oils were chlorinated and the resulting product then being treated with concentrated sulphuric acid. Here hydrogen chloride is split off and the intermediate olefines become subjected in a polymerization to high viscosity oils.

Gardener and Bielouss[11] investigated the thermal dechlorination of chlorinated paraffin petroleum fractions forming unsaturated hydrocarbon; in more recent times Tanaka, Kobayashi and Furumoto[12] succeeded in splitting chlorine from highly chlorinated solid paraffin wax obtaining very viscous oils which were said to be of lubricating nature. Many catalysts[13] have been proposed and are now being used to dechlorinate chloro derivatives as well as simultaneously polymerizing the resulting unsaturated hydrocarbons.

Of special interest are the investigations in which hydrocarbons of open- or straight-chain character are coupled with those of ring structure, since it is in this type of synthesis that one arrives at oils whose constitution more nearly approaches the natural lubricating oils. In this connection the interesting early work of Kramer and Spilker[14] should be mentioned, who were first able to obtain synthetic lubricants, and whose properties and constitution had been thoroughly investigated and determined. Their work dealt with condensation products obtained from styrene (also allyl alcohol) and the aromatic type of hydrocarbons, such as toluol, xylol, and cumol, using sulphuric acid as a catalyst.

Spilker[15] later proposed that the lubricant properties of these synthetic oils were due to the coupling of several ring hydrocarbons with aliphatic chains, as well as alkylation and that this structure was necessary for film-forming lubricants. The condensation of gaseous and liquid olefines, as well as chlorinated petroleum oils with the aromatic hydrocarbons has been described in the patent literature.[16]

The commercial manufacture of Paraflow,[17] for instance, belongs to this type of syntheses and in this case deals with the preparation of paraffinic lubricants which have the added property of lowering the pour-point of other lubricants. Paraflow is a viscous synthetic oil made by condensing a chlorinated hard paraffin wax (12 percent Cl) with an aromatic such as naphthalene, using aluminum chloride as a catalyst. The addition of a very small amount of this Paraflow to high pour-point oils prevents crystallization of the wax in the latter, eliminating the necessity of dewaxing such oils in order to lower the pour-point.

In another procedure[18] hard or soft paraffin wax or paraffinic oils are mentioned as the starting point for such condensation reactions. The waxes should be chlorinated to about 12-15 percent on added chlorine and can be then either dechlorinated by heating or can be subjected to a condensation with any of the aromatics using aluminum chloride as a catalyst.

Synthetic Oils from Kogasin

In view of the above literature review and the work of other investigators it became clear to us that in using kogasin as a raw material for making lubricants that we had three possibilities open in solving this problem. For example, it might have been possible to separate the olefines which are present in our synthetic product and use the olefines for polymerization.

We had reported earlier[19] that kogasin I contains appreciable quantities of unsaturated hydrocarbons in the fraction boiling up to 220° C., depending, of course, upon the particular conditions, such as kind of catalyst, type of raw gases, etc.; the unsaturateds so reported were obtained using a cobalt catalyst and a raw gas containing 27 percent Co CO and 56 percent hydrogen. In several investigations we were able to obtain a good yield of synthetic lubricants from a fraction of our synthetic benzine, (B.P. 150°-220° C.) using the procedure of Sullivan[9] with aluminum chloride as the catalyst.

Using this procedure, the low-boiling olefinic fractions were treated with approximately 5 percent of aluminum chloride and condensed to viscous polymers. Secondly, we employed the kogasin II which

TABLE 1

Relationship of the Olefine Content to Catalyst and Composition of Gases

Catalyst	Vol.-% Olefine in Syn. Benzine Using:		
	Water-Gas $1CO:1H_2$	Mixed Gas $1CO:2H_2$	Cracking Gas $1CO:3H_2$
Cobalt	55	35	12
Nickel	35	16	5

is much higher boiling and deficient in olefines, by first chlorinating to one or two atoms of chlorine in the molecule—that is, to the mono or dyed chlorol product.

These chloro-products were treated with activated aluminum metal until the material was free of chlorine, which indicated that the polymerization was completed. In this way white viscous oils were obtained. Finally, we also were able to synthesize lubricants of special qualities by taking kogasin and condensing it with aluminum chloride with aromatics, such as xylol. Lubricants by the third and last method show a much higher specific gravity than those made without the aromatics.

If it is intended to manufacture lubricants by the first method—that is, from the olefines—it is advantageous to know what fractions to employ and how to increase the olefine content of our low-boiling gasoline portions of the crude reaction product. Table 1 gives the compositions of the benzine fractions from various mixtures of gases used in the synthesis.

When using cobalt as a catalyst the olefine content in the gasoline fraction can be raised to 55 percent of the total; also, reversely, the olefine content can be depressed to as low as 5 percent, using nickel and cracking-gases enriched with hydrogen. Between these two extremes one can obtain various values for olefine content depending entirely upon the catalyst and on the hydrogen content of the syntheses gases. It is also possible, as we have proven earlier, to obtain even more than 55 percent of olefines or even less than 5 percent olefines by changing the relative quantities of carbon monoxide and hydrogen.

Table 2 shows the distribution of the olefines in the single fraction of the crude product, a kogasin manufactured from mixed gases.

TABLE 2

Distribution of Olefines in Crude Benzine

	Vol.-Percent	Olefine Contents Vol.-Percent
Total Raw Product	100	26
Cut: 50—100° C.	22.5	39
Cut: 100—150° C.	20.0	27
Cut: 150—200° C.	19.5	18
Cut: 200—250° C.	13.0	11

The total product, kogasin I plus kogasin II, shows 26 percent olefines; the fraction 50°-100° C. contains 39 percent. The higher-boiling fractions show a decreasing content of olefines with increase in the boiling point. For example, the lowest fraction of kogasin II, boiling at 200°-250° C., shows only a content of 11 percent.

TABLE 3

Polymerized Oils from Olefinic Kogasin Fractions

FRACTION	Specific Gravity d20/4	Viscosity: Engler Degrees at:		Visc. Index (Pohl Height)	V.I
		20° C.	50° C.		
50—100 C.	0.835	29.9	4.75	3.59	5
100—150	0.836	28.1	4.80	3.01	20
150—200	0.835	18.7	4.00	2.28	80
200—250	0.827	6.12	2.17	1.69	100

The properties of the lubricants made from the olefines separately in each of these fractions naturally depend upon the molecular weight of the olefines which are present in those fractions. In this connection the data in Table 3 gives valuable information.

For many purposes it can be said that the lubricants from the fraction 150°-200° C. would be the most practical to manufacture. Even though this synthetic oil would not have the best viscosity index it would, however, show a much lower pour-point. The viscosities shown in Table 3 can, of course, be raised considerably by distilling off in a vacuum the low-boiling-point portions—the less viscous material—obtaining more viscous residues.

From Table 4 it can be seen that the viscosity index appears to remain constant even though the viscosities may vary. This would indicate that while the molecule of the synthetic oil may vary (molecular weight), nevertheless the characteristics of the hydrocarbon, or structure, remain the same. For example, in Experiment No. 1 the original lubricant shows a viscosity of 18.7 E at 20° C., and after distilling therefrom some 40 percent of less viscous material the resulting viscosity showed 58.6 E. The viscosity index of the residue is practically identical with that of the distillate.

A similar result was obtained in Experiment No. 2. As raw material for preparing the lubricating oil we used a kogasin fraction of 125°-250° C. It is noteworthy to point out the high viscosity of lubricant No. 3 obtained by distilling off 50 percent of lower boiling material. Oil No. 3 shows 17.1 E at 50° C. This very viscous oil nevertheless shows an excellent pour-point of —30 C.

TABLE 4

Vacuum Distillation of Two Synthetic Lubricants

Exp. No.		Visc. Engler Degree at			Visc. Index	(Phol Height)
		20 C.	50 C.	100 C.		
1	1 Raw Lube-Oil I	18.7	4.0	.....	2.28	(70 V.I)
	Removing by dist'n 20 vol. % of above gives residue:					
	Lube-Oil II	34.8	6.0	.....	2.47	
	Dist'n of another 20% (vol.) yields residue or					
	Lube-Oil III	58.6	9.04	.....	2.31	
	Distillate I (20% of I)	3.06	1.56	.....	2.30	
2	2 Raw-Lube-Oil I	20.8	4.7	1.62	1.9	(90 V.I)
	Removing by dist'n 30% vol. % gives residue:					
	Lube-Oil II	57.8	9.6	2.06	2.12	
	Dist'n of another 20% vol. cut yields as residue:					
	Lube-Oil III	123.	17.1	2.68	2.18	
	Distillate I	3.03	1.59	.....	1.77	(100 V.I)
	Distillate II	13.9	3.36	.....	2.0	

Testing the Synthetic Oils

The synthetic oils made by the three various procedures mentioned above have been subjected to many tests and careful evaluation. Table 5 gives the results of these tests on a lubricant made from a kogasin fraction 150°-200° C., using aluminum chloride as a catalyst.

Special mention should be made of the great stability of this oil against oxidation when tested by the Sligh method. Samples left standing in sunlight and air for several years did not deteriorate or darken in color as did oils from natural petroleum refined in the usual manner. The oil shows a very low carbon value by the Conradson method and an exceedingly low pour point of —33 C. It was shown in practical automobile tests over a long period made at our institute

TABLE 5

Analytical Constants of a Synthetic Oil

	Oil From Kogasin Cut 150-200 C.
Spec. Grav. 20 C.	0.836
Ref. Index (D) 20.	1.4658
Spec. Refraction.	0.558
Flash-Point (open) C.	197
Visc. Engler Deg. 20 C.	19.4
Visc. Engler Deg. 50 C.	4.0
Viscosity Index.	50
Sligh-Oxidation Test.	None
Conradson Carbon.	0.02%
Pour-Point.	below—33 C.

that synthetic oils of similar viscosity gave results in every way as good as auto-oils made from natural petroleum; these practical tests were made in automobile engines of several different designs.

It is interesting to tabulate a comparison of the synthetic lubricant with a winter grade of oil used for automobiles. Table 6 shows this comparison between the two oils, the commercial lubricant bought on the market being about the same viscosity at 20° C. as our synthetic oil.

The synthetic oil shows a rather low specific gravity, this going hand-in-hand with its high content of hydrogen. It also shows a very low pour-point, much lower, than the commercial automobile oil. Concerning fluidity at low temperatures, this property was measured in a U-tube and determined for both oils. At —15° C. our oil flowed to the extent of 30MM., the commercial oil only 3.5 MM. Even at —25° C. the synthetic oil remains fluid under kinetic conditions to the extent of 30 MM., the commercial oil no longer flowing at that temperature. From the results in this table it is possible to make very high grade lubricants from the olefines in kogasin.

Concerning the color of our synthetic oils, it can be said that this property can be varied according to the method of preparation. The colors are not at all characteristic of any of the properties of these oils since the properties can be left practically the same after our synthetic oil is subjected to an hydrogenation process. Hydrogenation is very well adapted for these oils since they are free from sulphur and a nickel catalyst with hydrogen at a fairly low temperature results in oils that are practically water-white. Even with this great color improvement the properties of the resulting oil are just about the same as the original lubricant, showing that color is not a characteristic property of these synthetic oils.

Mention should be made concerning the constitution of the olefine synthetic oils. The average molecular weight of the olefines employed point to their composition as being $C_{10}H_{20}$. The oils obtained from the olefines show a molecular weight of 450, so that one can draw the conclusion that at least three olefine molecules of the above formula polymerize to one lubricant molecule. The hydrogen content of the olefines show 14.4 percent by weight, and the hydrogen content of the synthetic lubricant, which was formed under the influence of aluminum chloride, shows 14.2 percent by weight.

TABLE 6

Comparison of a Commercial Petroleum Lubricant and a Synthetic Oil

	Commercial Winter-Oil	Synthetic Oil
Spec. Grav. 20 C.	0.882	0.838
Visc. E. Degrees 20 C.	32.6	32.0
Visc. E. Degrees 50 C.	6.10	6.06
V. I.	60—70	60—70
Pour-Point.	—16 C.	—42 C.
Fluidity (U-Tube method) at:		
—15 C.	3.5 mm	30+ mm
—25 C.	0.0 mm	30+ mm
Flash-Point, open.	220 C.	205 C.

As already pointed out, this percentage is uncommonly high and is the reason for these oils showing such excellent stability. The average approximate formula for these lubricants appears to be between $C_{30}H_{60}$ and $C_{30}H_{58}$. A much closer estimation will be made in the future when we shall obtain closer-cut olefine fractions, practically pure C_{10} olefines, and use such material for the polymerizations instead of fractions which are mixtures approximating a C_{10} olefine.

From an over-all, practical standpoint of interest to the refinery manager it is, of course, desirable to know the relative quantities of benzine and lubricants that are obtainable in the Fischer-Tropsch water-gas process. In this connection the following can be mentioned. If the lubricants are made from the olefines of the primary product (especially the olefines from the water-gas product), then the relative amounts obtained are eight parts of benzine and one part of lubricant—that is, a ratio of eight to one. This relationship is much better than that existing in the automobile industry where more than eight times as much gasoline is used compared to the lubricant used by civilians.

If the solid paraffins or the cracked olefines are also brought into play and converted to lubricants the relationship of benzine to lubricant of course become very advantageous for commercially applying the Fischer-Tropsch process.

The third possibility lay in using the high-boiling fraction from our synthetic process, namely kogasin II. It seemed more important to work eventually with this material than with the synthetic gasoline since the former appeared to have less value at this time as a diesel-motor fuel. In contrast to the synthetic gasoline, kogasin II contains a very much lower amount of reactive olefines. As a matter of fact, the content of olefines decreases rapidly with increase in the boiling point in these synthetic products amounting to 35 percent in the synthetic gasoline but only 10 percent in kogasin II. Using nickel catalysts which are strongly hydrogenating one obtains an almost completely saturated kogasin II. It is this type of product which we have used in the work which we will now describe. The physical and chemical tests of kogasin II have already been described in a previous investigation.[20] Judging from its specific gravity, the ultimate analysis, and the average boiling point, it can be said that kogasin II consists of hydrocarbons of composition $C_{14}H_{30}$—namely, tetradecan.

Chlorination of Kogasin

Basing our work on the statements made above, namely that most of the natural lubricants are ring systems with paraffin-chain connections, or alkylated rings, we have next determined what are the properties of synthetic lubricants made by the condensation of kogasin II with ring hydrocarbons.

In order to make the kogasin reactive it was first converted with gaseous chlorine into a series of chlorinated derivatives. The products contained one, two, and up to six chlorine atoms per hydrocarbon molecule based upon the above molecular weight of kogasin. Chlorine displaces the hydrogen in the molecule very easily at ordinary rates and there is a practically quantitative conversion, half of the chlo-

TABLE 7

Kogasin II and its Chlorinated Products

Degree of Chlorination	Weight Increase After Chlorination	% Cl	Spec. Grav. 20 C.	Viscosity E. at 20 C.	Viscosity E. at 50 C.
Kogasin II	0	0	0.774	1.36	1.13
Mono-chloro-Kogasin II	17.4	14.8	0.872	1.67	1.27
Dichloro-Kogasin II	34.8	25.8	0.977	5.1	1.5
Trichloro-Kogasin II	52.2	34.3	1.057	6.5	2.1
Tetrachloro-Kogasin II	69.5	41.0	1.139	27.3	4.4
Hexachloro-Kogasin II	104.3	51.0	1.292	570.0	28.5

rine entering the hydrocarbon molecule, the other half of the chlorine used being evolved as hydrogen chloride. The chlorination is allowed to take place under stirring conditions and carried out at room temperature. Data is given in Table 7 concerning some of the properties of these various chlorkogasins.

It can be seen that the viscosity of these products increases only slightly with increasing chlorine content but then increases very rapidly from tetrachlorkogasin upward. The hexachlor product is already so viscous that it can hardly be stirred at room temperature. In order to prepare products containing greater amounts of chlorine, which up to the present have not been attempted, one would be compelled to chlorinate and work at some higher temperature.

Condensation of Chlorkogasin by the Friedel-Craft Reaction

For the purpose of again splitting off chlorine during the simultaneous condensation of kogasin with an aromatic ring one finds the Friedel-Craft reaction using aluminum chloride to be well adapted for the synthesis. This procedure was used by Halse[21] in preparing alkylated benzols with long side chains, namely, tridecyl and pentadecyl benzol. These compounds were obtained as thick aromatic type of liquids. We were especially interested to work with these variously chlorinated kogasins since these products had never been investigated by other chemists in this field. Various aromatics, such as benzol, toluol, and the xylols were employed in the condensation. Most of our experiments employed pure xylol, the commercial grade containing the three isomers, and we are well versed in the manner in which the reaction takes place and also acquainted with the many factors in the use of xylol.

Concerning the various conditions in the reactions which we employed it can be said that we proceeded as follows: the chlorinated kogasin is mixed with a three-fold volume of the aromatic and to this mixture 10 percent of anhydrous aluminum chloride is added on the weight of the chlorinated product. The mixture is well stirred and the reaction takes place at room temperature. The reaction is speeded up by warming the apparatus on a water bath. After a period of time the mixture is allowed to settle and the solution containing the reaction product is decanted from the heavier aluminum chloride sludge below. The solution is next washed and treated with a small amount of bleaching clay, such as tonsil, followed by distillation to remove the excess aromatic hydrocarbon still present.

The crude reaction material now obtained is subjected to a vacuum distillation up to about 200° C. at 12 MM pressure in order to remove low-boiling oils and to obtain a residual oil of the proper flash point. The synthetic oils obtained in this manner which are of medium to very high viscosity are mostly of reddish color (depending upon the amount of bleaching clay used), are transparent oils and show the typical cast for lubricating oils, although some of our products are very pale yellow in color with only a slight cast.

The products are free of chlorine, usually below 0.1 percent. The aluminum chloride sludge obtained in the reaction can be re-used as further catalyst in following treatments although it is most common to add a small amount of fresh anhydrous aluminum chloride in order to obtain subsequent products which are absolutely free of chlorine.

The conversion using xylol with various chlorinated products comprises our first series of experiments. Table 8 shows in brief form the properties of the synthetic oils and the yields obtained using xylol as the aromatic.

TABLE 8

Conversion of Xylol with Various Chlorkogasins

Chloro Product Used	Times Reacted	Spec. Grav. 20 C.	Visc. °E. at: 20 C.	50 C.	100 C.	Yield (on Chloro-Product (Vol.)
Dichloro-Kogasin	1	0.904	15.8	3.4	....	76
	2	0.905	27.4	4.7	....	77
Trichloro-Kogasin	1	0.925	35.0	5.2	....	75
	2	0.937	80.0	8.7	....	96
Tetrachloro-Kogasin	1	0.958	....	16.8	2.2	66
	2	0.978	....	54.8	3.3	105
Hexachloro-Kogasin	1	0.992	....	53.6	2.7	39
	2	1.008	....	316.	5.7	58

As can be seen from the above, the density of the finished product increases rapidly in relation to the chlorine contents—namely, from 0.9 with the dichloro products to 1.0 in the case of the hexachlor products. This fact can be explained that for every atom of chlorine in the molecule which is split off, a C-C bond is formed, which always results in a denser chain of the atoms in the condensed molecule.

In line with the increase of specific gravity there is a corresponding increase of viscosity of from 3.4 E at 50° C. to the extremely high value of 316 E at 50° C. It should be further pointed out that in subsequent condensations using spent aluminum chloride sludge oils are obtained which are considerably more viscous than those obtained in the first condensation using fresh aluminum chloride.

It is also noticeable that in subsequent reactions using the aluminum chloride sludge that the percent of final oil (the yield) increases based on the quantity of chloro product used. The explanation for this observation seems to be that the aluminum-chloride-sludge actually appears to enter into the reaction, and already containing oil in its combination, does not add additional reaction product as would fresh aluminum chloride during the stage of sludge formation.

The conversion of trichlorkogasin with xylol employed altogether seven consecutive aluminum-chloride-sludges—using each time as catalyst the sludge from the previous reaction. It is important to notice that the increased viscosity obtained in the second reaction remained high throughout the rest of the condensations. Changes in the properties of the oils is not always a constant factor even when the reactions are carried out under exactly the same conditions. Unknown factors which we have not yet determined appear to yield at times oils of various viscosities. It can be said that 5 percent by weight of aluminum chloride based on the chlor product is quite sufficient to carry out the condensations with the above aromatics.

As already mentioned, we have also carried out the condensation of the chlorkogasin with other aromatic hydrocarbons, such as with benzol, toluol, naphtha-

lene, methylnaphthalene, and tetralene; results have shown that the reaction with these aromatics proceeds in a manner similar to that as with xylol. The effect of the constitution of the aromatics in relation to the properties of the synthetic oils has not been investigated further at this time but we intend to initiate experiments in this direction.

An insight into the type of oils obtained using the tetrachlorkogasin with benzol under the same conditions as in the case of xylol can be seen from an inspection of Table 9. According to these results the oils are considerably denser although the viscosity does not greatly vary from one to the other. The yields in the case of using benzol are considerably less than when xylol is employed.

TABLE 9
Comparison of Synthetic Oils from Tetrachlorkogasin Using Benzol and Xylol

Tetrachloro-Kogasin Reacted with:	Re-acted	Spec. Grav. 20 C.	Visc. °E. at 50 C.	Visc. °E. at 100 C.	Yield (Vol.-%) on Chloro-Product
Benzol	1	0.967	15.8	2.2	43.
Xylol	1	0.958	16.8	2.2	66.5
Benzol	2	0.981	36.1	3.0	64.
Xylol	2	0.978	54.8	3.3	105.

Concerning the weight relationships in which the chloro derivatives enter into reaction with the aromatics there have been no satisfactory calculations made up to the present time. Any scheme to present the direction in which these reactions might proceed is always to some extent obscured by the fact that the aluminum chloride addition-compound (sludge) will usually react with one of the other components, forming further complex insoluble material. Added to that is the fact that kogasin, being a somewhat complex hydrocarbon mixture, is certainly not chlorinated into definite or single chloro derivatives during the process of chlorination.

For a close calculation or balancing of the many side reactions which take place during the condensation one would be compelled to investigate carefully not only the lubricant portions of the synthetic oil which are formed but also to take into account an analysis of the low-boiling synthetic material which is also formed in somewhat lesser quantities.

In view of the above we believe that it can be said that in the case of reacting trichlorkogasin with xylol, as a first approximation 1.5 molecules of the aromatics enter into a reaction with one molecule of the chloro product. Now it has been shown that the high-boiling synthetic oil possesses an average molecular weight of about 450, pointing to the combination of one kogasin molecule with two aromatic rings. In the case of the synthetic light oils which are also formed but in smaller amounts it can be said that the condensation is between one or two paraffin chains with only one aromatic ring. We intend to continue work to prove more fully these opinions.

Analyses of the Synthetic Oils and Their Value as Lubricants

It is customary to judge lubricating oils by many other constants besides the test for viscosity and that other properties may be determined before a practical evaluation can be given. Table 10 gives the most important tests of two of the synthetic oils which have been subjected to more critical tests. These

TABLE 10
Tests on Two Synthetic Oils

TESTS	Oil No. 1 from Tetra-chloro Kogasin with Xylol (3 Times Reacted)	Oil No. 2 from Trichloro-Kogasin with Xylol (Twice Reacted)
Spec. Grav. 20° C.	0.9738	0.9351
Visc. °E. at 20° C.	.....	101
50° C.	49.1	10.84
75° C.	8.7	.....
100° C.	2.9	1.87
V.-Index	Below 0	90
Pour-Point	—1° C.	—20° C.
Conradson Carbon (percent)	0.26	0.17
Sligh-Oxidation No.	11.6	1.0

tests were conducted in our laboratory by Dr. R. Koetschau and Dr. G. Schmidt.

In summarizing the above anaylsis it can be said that it is of no great advantage to produce oils of extremely high viscosity, as in the case of oil No. 1, since it results in a degradation of the other properties of the oil. For this reason it is important in the chlorination of the kogasin to limit the chlorination, forming no higher chloro product than the trichloro derivative, since these extremely-high-viscosity oils are already produced using the tetrachloro product. The tests on oil No. 2 show that it has satisfactory low temperature properties of viscous Texas oils and is a valuable lubricant also from the standpoint of greater oxidation stability.

Hydrogenation of the Synthetic Oils

In connection with the above results we next sought to answer the question whether or not the condensed alkylated oil with a benzine ring could be improved by hydrogenation—that is, hydrogenating in the ring. For this purpose we therefore conducted experiments in an iron autoclave subjecting the synthetic oils to pressure hydrogenation using a nickel catalyst. Hydrogen absorption began at 130° C.; however, in order to increase the speed of the reaction a temperature of 190° C. was optimum. Under these conditions there was no formation of gases or low-boiling cracked products. Upon completing the hydrogenation the saturated oils were obtained as crystal-clear products after separating them from the catalyst. The catalyst was further washed with benzine to remove oils and upon steam distilling the solvent, a heavier yellow oil with blue cast was obtained.

Concerning the amount of hydrogen which went into the reaction, we found that 470 grams of oil (1 mol.) consumed approximately 5.5 mols of hydrogen. This fact seems to substantiate a previously mentioned calculation that the synthetic oils contain approximately two benzol rings which absorb 6 mols. of hydrogen during hydrogenation. Table 11 gives a comparison of the hydrogenation of the oil which was synthesized from trichlorkogasin and xylol.

As can be seen, the specific gravity decreases from 0.940 to 0.894 and the latter figure is characteristic for commercial grades of lubricants. The viscosity is

TABLE 11
Effect of Hydrogenation on the Gravity, Viscosity, and Chemical Constitution

Syn. Oil from Xylol and TrichloroKogasin	Spec. Grav. 20 C.	Visc. °E. at 20 C.	Visc. °E. at 50 C.	Ultimate Analysis %C.	Ultimate Analysis %H.
Before Hydrogenation	0.940	110	10.7	88.6	11.13
After Hydrogenation	0.894	63	7.7	86.66	13.19

TABLE 12

Comparison of Tests of Hydrogenated Oil with Original Synthetic Oil

	Oil No. 1 Not Hydrogenated	Oil No. 2 Hydrogenated
Spec. Grav. 20° C.	0.9351	0.8944
Ref. Index 20° C.	1.5300	1.4909
Spec. Refraction	0.5661	0.5489
Flash-Point, open (°C.)	204	190
Fire Test (°C.)	242	220
Visc. °E. at 20 C.	101.	61.9
50 C.	10.84	8.02
100 C.	1.87	1.73
150 C.	1.25	1.22
V. Index	5	10
Sligh-Oxidation Test	1.	None
Conradson Carbon Residue	0.17%	0.03
Acid No.	0.06	0.02
Saponification No.	0.51	0.03
Pour-Point °C.	—20	—27

considerably reduced when the oil combines with hydrogen; the ultimate anaylsis shows a reduction in carbon of about 2 percent. A large sample which had been hydrogenated in another laboratory was subjected to more extensive analysis as shown in Table 12. Here data is given for the hydrogenated as well as the original oil.

It can be seen that the hydrogenated oil is a true low-pour-point lubricant, characterized by a very high stability towards oxygen, and showing a very low coke value. By hydrogenation it has been possible to reduce the viscosity index from 3.5 to 3.2, which indicates the latter oil to be relatively rich in hydrogen and approaching the high grade Pennsylvania oils.

The final oil is practically a white oil although white oils are usually not produced with viscosity as high as in our finished oil. The hydrogenated oils, moreover, show no loss in film or lubricant value due to hydrogenation, as is customary when white oils have been manufactured using the usual sulphuric-acid treating process. There is therefore no reason to suspect that these water-white hydrogenated oils are not true lubricants such as the usual yellow-, green- or blue-cast commercial oils, since the tests shown in Table 12 indicate the final oil to have exceedingly valuable properties comparable with the best commercial oil from natural petroleum. However, we are continuing our hydrogenation work to obtain larger samples which can be subjected to commercial engine tests and further prove their value in actual commercial applications.

It has been shown by the above experiments that valuable commercial lubricating oils can be manufactured by condensing aromatic hydrocarbons with kogasin obtained in our water-gas reaction. It is, of course, possible that the route by way of chlorinating the kogasin could be eventually by-passed or omitted and that chlorination is not the only means of conducting a successful condensation with the aromatic. The procedure we have used, however, was valuable in obtaining certain data which we have presented and we have obtained synthetic oils which may be said to present an entirely new type of hydrocarbon; and that we have obtained an insight into the properties and constitution of such synthetic oils; by our procedure we have shown the type of lubricant that one might expect in similar condensations made by analagous procedures.

Summary

1. Various procedures have been given to prepare synthetic lubricants. Their properties and composition have been compared with those oils obtained from natural petroleum.

2. Starting with kogasin one can also obtain lubricants from the olefine hydrocarbons present in the low-boiling benzine range—the synthetic benzine obtained in the water-gas reaction.

3. Kogasin II, that is, the gasoil fraction of the synthetic petroleum from carbon monoxide and hydrogen, was converted into a series of chloro-products and these were condensed in a Friedel-Crafts reaction with aromatic hydrocarbons.

4. Variations of various factors on the properties of the viscous oils were investigated. A closer analysis of two synthetic oils showed that they simulate very closely the properties of naphthene-base-petroleum lubricants.

5. By way of hydrogenation the synthetic hydrocarbons prepared from kogasin can be converted into less dense and water-white oils. These hydro-oils appear to possess extremely great stability toward oxidation, a minimum of carbon formed on coking, and a very desirable low pour-point.

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Gaining Safety Through the Intensive Participation of the Employee

P. C. SHEA,
Vice President, Colonial Beacon Oil Company

AFTER the safety record at the Colonial Beacon Oil Company plant had been properly celebrated earlier this year, the effort was made to get the methods of accomplishment put into an article. Finally P. C. Shea sent along some notes with the suggestion that they be expanded into an article.

Several efforts at this expansion resulted in a decision that should have come sooner. His notes were complete, which is all that good writing requires. Other than a few changes of minor consequence, this explanation of how to accomplish safety in a refining plant is the set of notes he prepared.

Number on the Safety Board shown above was 830 at the time these notes were prepared.

MR. CHAIRMAN, I have a suggestion to make concerning the condition of the floor in the machine shop. It is a wood-block floor and sections are heaving up and causing a serious tripping hazard."

You have just eavesdropped on a typical incident in a session of the labor-management-workmen's safety committee at the Esso refinery of the Colonial Beacon Oil Company, Everett, Massachusetts, where on December 14, 1943, two years of operation without a disabling injury was completed.

It is significant that this record had its start the week following the attack on Pearl Harbor. Over that period not a single employe of the manufacturing department lost a day from the war effort. A serious accident might well have reduced the output of desperately needed war fuels.

Labor-management committees have been part and parcel of our operations for a long time. With the coming of war their value came into special recognition. They have formed the backbone of our organization for safety.

Safety On a War Basis

One of the beneficial results that came to our country when it was attacked was the widespread formation of the labor-management war-production-drive committees. Our war-production-drive committee was formed in 1942. This committee immediately undertook the supervision and coordination of the work of all the other active operating labor-management committees, which were dealing with single problems. One of these was the safety committee.

This workmen's safety committee, established in the fall of 1929, has consistently been a potent factor in promoting safety in the plant. It is composed entirely of hourly-paid employes and its personnel is changed each four months. Its activities have the guidance of a safety engineer.

Each member represents a certain group of fellow

LABOR-MANAGEMENT COMMITTEE

nding, left to right: J. F. Lyons, C. H. Cole, R. N. McGinniss, E. D. Lawrence, I. J. Staid, J. F. Bradley, and W. D. Summer; seated, left to right: J. O'Rourke, secretary; F. S. Hunt, H. W. Milliken, co-chairman; J. E. Murphy, co-chairman; L. E. Denning, Gregory Goulski and R. L. Courtenay.

Left to right: W. F. Horton, laboratory; E. D. Petipas, machine shop; L. G. Dingee, boilermaking; J. J. Long, labor; Joseph Gallant, pipe; Albert Joyce, pumping; E. R. Swanson, safety supervisor.

Members of the workmen's safety committee at Colonial Beacon Oil Company refinery in session.

employes, from whom he collects ideas, suggestions and solutions. At each bi-weekly meeting accidents are discussed and methods of prevention suggested. Suggestions regarding possible plant hazards are considered and safe working procedures are outlined. These are then passed along to the foreman's committee for action.

During his term on the committee each member is undergoing a training course in safety. He gets an intensive contact, impossible to give all employes. Over a long period, however, this intensive training comes to each employe because of the frequent changing of committee membership.

The Membership Relay

At the end of each four months, a dinner is arranged. The outgoing and the incoming members thus have the benefit of exchanging ideas and intimate acquaintance. At the close of the dinner there is a simple little ceremony in which the former members pin their badges on the individuals of the new committee. At the same time the management has an opportunity to present the outgoing members with a token of appreciation. Recently this has consisted of a small first-aid kit in a metal container.

The record of the year 1930 is an example of the effectiveness of the workmen's safety committee. During 1929 records show that the plant had 207 minor injuries, of which 41 were of the disabling classification. In 1930, the first year during which the committee functioned, there were only 107 minor injuries, only 6 of which were of the disabling class. In 1931, disabling injuries dropped to 4, and in 1932 just 1 was recorded. The number of minor injuries decreased accordingly. Finally, the plant personnel went through 1942 without a disabling injury, and repeated this record in 1943.

It's Up To the Foreman

In recent years the role of a foreman or supervisor had expanded greatly. He is expected to lead and instruct his group effectively. The success of a safety program depends to a great extent on foremen. Teaching and directing men in safety matters frequently is something new for a foreman. He must be taught how to teach and to lead. He has to be supplied with knowledge and methods, tools of his new occupation.

Our foremen participate in training conferences in which they become familiar with training methods. They have their own safety committee whose meetings afford opportunities for discussing accidents, determining preventive measures, formulating safety workmen's committee, such as the report on the rules and acting on suggestions that come from the condition of the wood-block floor. They are provided with literature and material, which allow them to keep well informed in all phases of safety.

Literature on safety should be both local and national in origin. Inter-plant and intra-plant letters and bulletins, state pamphlets and national magazines will give them, among other things, the interesting topics they need for regular talks on safety.

Talks Fit the Occasion

Our formal departmental talks on safety are arranged by each foreman each month. They are carefully planned and executed and are deliberately different from the short, snappy, daily talks so frequently given to small groups just starting on jobs. The complete personnel of the department is present. A report of the meeting is included in the record of the next foremen's safety committee.

Facing the plant gates we have a large, conspicuous safety board. The number of accident-free days has a prominent place along with pertinent posters and other evidence of safety. Both incandescent and neon lighting are used to draw attention and a clock has been built into the board to assure attention from employes.

This type of safety organization, calling for intensive participation of the individual employe, is limited for practicability to a plant having from 500 to 750 workmen. There is every reason to believe, however, that in a larger plant it could be adapted by restricting it to departments. In some instances, of course, it might be necessary to have several departments combined. In others, where the personnel of a department is large, it might be advisable to divide the department so as to arrive at suitable groups.

Success of such an organization presupposes that management has established and maintains sound personnel relations and good working conditions that management itself recognizes that safety is an integral part of the overall production plan of the unit.

Application of Unit Operations To Fractionation and Other Vaporization Processes

PART 6

Stage Separation of Mixtures Containing Three or More Hydrocarbons

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WITHIN the past few years a knowledge of stage separation has become as essential for the engineer in the natural-gasoline plant as it has been for the oil-producing engineer. This realization has been brought about by reason of the close relationship existing between the plant and the field operators in their efforts to work out recovery plans which may net the greatest returns per dollar of investment to all parties concerned. This cooperation has been evident, not only between these two departments under common ownership, but also among plants and producers where different companies are involved. In certain instances, the effective operation of several separators in series has reduced the gross gallonage of natural gasoline available in the gas streams, but at the same time it has enabled the gasoline manufacturer to process these gas streams with a greater return on his money, through elimination of oil absorption costs. In other cases, the gross gallonage has been boosted for the gasoline plant, where the oil producer has been keen enough to realize that in the absence of stabilization the retention of too much natural gasoline in the crude oil or in "distillate" production may result in prohibitive evaporation losses on the lease and in transit to the refinery.

Three Processes Involved

(1) Flash or Equilibrium Vaporization—This process involves steady-state flow, in which the vapor evolved, or liquid condensed, is in equilibrium with the other phase. The refiner has found that this type of continuous operation is advantageous in the distillation of crude oil, not only from the standpoint of simplifying the process but also in view of the release of vapor greater in amount that it would be possible to obtain through batch or differential vaporization. Through the work of Piromoov and Beiswenger,[6] the "flash" vaporization of a crude oil can be easily calculated through an empirical relationship between the true boiling point, or differential distillation, and the flash curve. In Figure 1, a typical set of flash and differential curves is shown. It is easy to see that with the exception of the front end of the curves, the flash curve gives a greater vapor release for any one temperature.

(2) Batch or Differential Vaporization—The shell still represents an illustrious type of differential vaporization, in which the refiner used to distill his crude oil by the batch process. The ordinary laboratory tests, such as the ASTM, the Hempel, and the true-boiling-point fractional distillations, also involve the same type of vapor release, in that the vapor is removed from the liquid under constantly changing conditions. In the batch operations just mentioned, the pressure is usually held constant, while the temperature is gradually increased; however, in carrying out the true-boiling-point analysis, both the decrease in pressure and the increase in temperature are resorted to as a matter of convenience in removing the

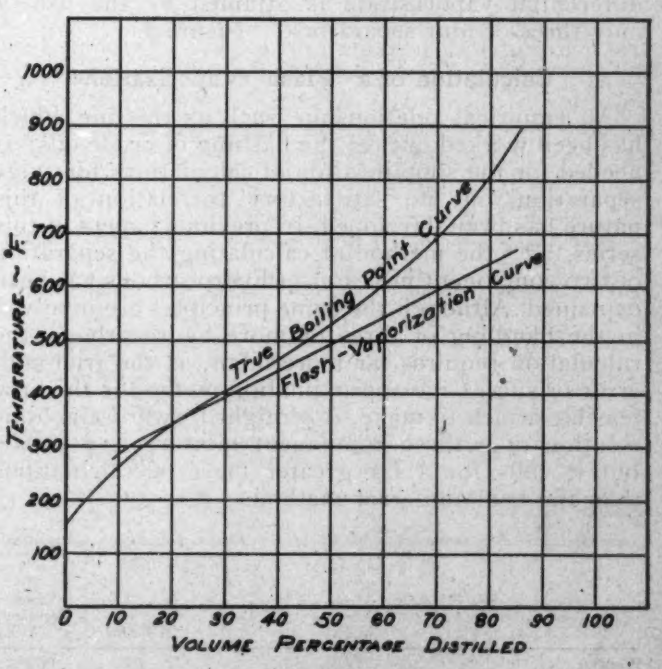

FIGURE 1

Flash and Differential Vaporization curves from Pennsylvania crude. (From Nelson, "Petroleum Refining," McGraw-Hill Book Company)

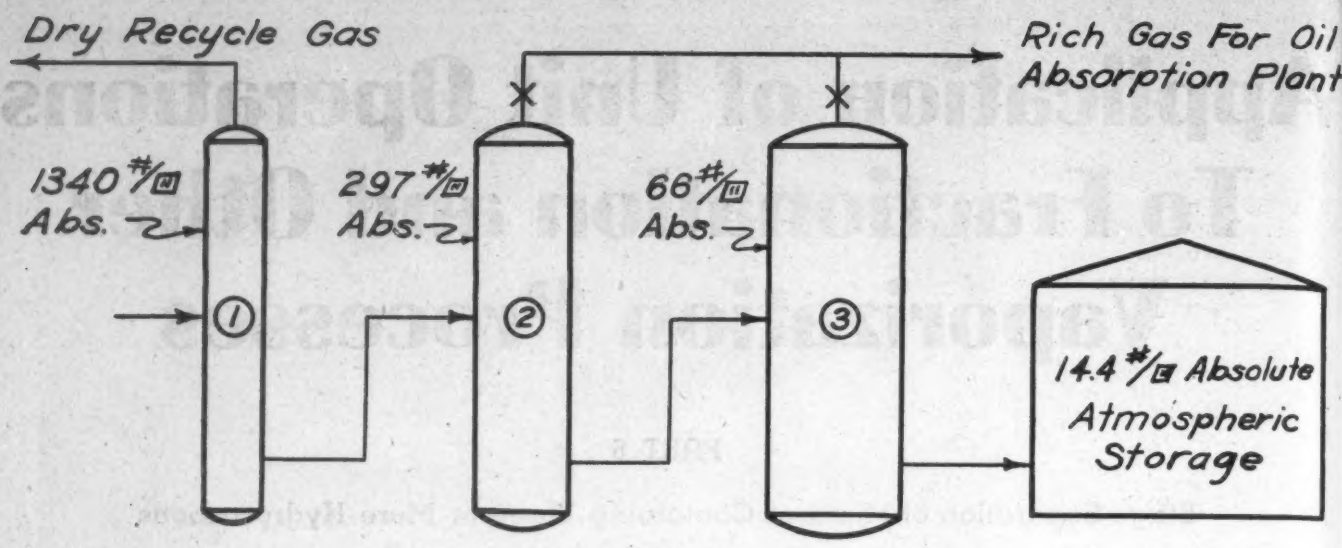

FIGURE 2

Diagram of a three-stage-separation installation with a pressure reduction ratio of 4½ to 1.

overhead stream as vapor. Rayleigh[7] has derived an equation for differential or batch distillation.

(3) Combination Flash and Differential Vaporization—This type of operation is found in the stage separation of crude oil-gas mixtures. The refiner usually wants a maximum release of vapor from the crude in distillation practice, whereas the oil producer more often prefers to retain the maximum amount of volatile fractions in the crude oil as it flows from the final separator into storage. For this reason, differential vaporization or condensation is sought by the oil producer. Since differential vaporization or condensation, in the true sense, would involve a batch operation or an infinite number of separations under a continuous steady-state process, the most practical alternative has been evolved through the development of stage separation. By means of a steady-flow system, in which the pressure is progressively lowered in each separator, a close approach toward true differential vaporization is attained by the use of only three or four separators.[4, 5] Figure 2.

Calculation of a "Flash" Vaporization

An empirical relationship, such as the one which has been worked out for the flashing of crude oils,[6] is needed for the simplification of calculations for stage separation, but no satisfactory correlation of this nature has been developed. In previous papers of this series, [1, 2, 3] the method of calculating the separation of two component mixtures of hydrocarbons has been explained. Although the same principles are involved in the handling of three or more hydrocarbons, the calculation requires far more labor, as the trial-and-error or successive approximation method is the only feasible attack to make. A straight forward algebraic solution of a three component mixture is possible, but it calls for a far greater mass of calculations than the trial-and-error method.

A material balance can be made around a separator into which a stream is flowing, and from which vapor or gas is being removed overhead, and a liquid stream is flowing from the bottom, as shown in Figure 3.

Since the entering stream is quantitatively equal to the outgoing vapor and liquid streams, the balance for any one component may be expressed mathematically:

$$\underset{\text{Input}}{X_f} = \underset{\text{Vapor}}{V(Y_v)} + \underset{\text{Liquid}}{(1-V)\,X_L} \tag{1}$$

Since $\pi\, Y_v = P\, X_L$ (from Raoult's Law)

$$X_f = V\left(\frac{P}{\pi}\, X_L\right) + (1 - V)\, X_L \tag{2}$$

$$X_f = X_L\left(V\frac{P}{\pi} + 1 - V\right) \tag{3}$$

$$X_f = X_L\left[1 + V\left(\frac{P}{\pi} - 1\right)\right] \tag{4}$$

$$X_L = X_f \Big/ \left[1 + V\left(\frac{P}{\pi} - 1\right)\right] \tag{5}$$

If Henry's Law is used, equation (5) can be expressed:

$$X_L = X_f / [1 + V\,(K - 1)] \tag{6}$$

Since $Y_v = K\, X_L$

Whenever a mixture of hydrocarbons is subjected to compression at temperatures above their combined freezing point, one of three things in general may take place.

1. Total vaporization of the mixture.
2. Partial vaporization or condensation.
3. Total condensation.

Bubble Point or Initial Vaporization

For example, a natural gasoline mixture of three paraffin hydrocarbons consisting of:

	Mol%
Propane	30
Normal Butane	30
Normal Pentane	40

is pumped through a coil and into a separator main-

	Mol. Frac.	Vapor Pressure at 100° F.	$\frac{P}{\pi}$	$\frac{P-1}{\pi}$	Let V=0.4 (first trial) $V\left[\frac{P-1}{\pi}\right]$	$1+V\left[\frac{P-1}{\pi}\right]$	X_L	$Y_v = \frac{P(X_L)}{\pi}$
Propane	0.3	187.0	3.11	2.11	.844	1.844	.1625	.5050
N Butane	0.3	52.2	.87	—0.13	—.052	.948	.3160	.2740
N Pentane	0.4	15.6	.26	—0.74	—.296	.704	.5680	.1480
							1.0465	.9270

tained at 100° F. What pressure must exist in the separator to cause the mixture to be entirely liquefied, but at the point of initial vaporization (bubble point)?

By applying Raoult's law, an equilibrium balance can be set up for each hydrocarbon between the liquid and the small bubble of vapor, assuming the amount of vapor formed is insufficient in quantity to cause the liquid to change appreciably in composition.

Partial Pressure in Vapor = Partial Pressure in liquid.

Total Pressure X mol fraction in vapor = vapor pressure X mol frac in liquid.

(7) Propane $\pi Y_3 = 187$ (.30)
(8) N Butane $\pi Y_4 = 52.2$ (.30)
(9) N Pentane $\pi Y_5 = 15.6$ (.40)

$$Y_3 + Y_4 + Y_5 = 1$$

Adding each side of equations (1), (2) and (3)

$$\pi = 187\ (.30) + 52.2\ (.30) + 15.6\ (.40) = 78.25 \text{ lbs. sq. in. abs.}$$

The composition of the bubble of vapor can be solved by substituting the value of π or total pressure into the above equations.

$$Y_3 = \frac{187\ (.30)}{78.25} = 0.72 \text{ Mol frac of propane in bubble}$$

$$Y_4 = \frac{52.2\ (.30)}{78.25} = 0.20 \text{ Mol frac of N Butane in bubble}$$

$$Y_5 = \frac{15.6\ (.40)}{78.25} = \frac{0.08}{1.00} \text{ Mol frac N Pentane in bubble}$$

In a similar manner, the point at which total vaporization of the liquid occurs is obtained by setting up equilibrium equations.

(10) Propane $\pi .30 = 187\ X_3$
(11) N Butane $\pi .30 = 52.2\ X_4$
(12) N Pentane $\pi .40 = 15.6\ X_5$

$$X_3 + X_4 + X_5 = 1$$

By expressing the liquid fractions in terms of π, such as

$$X_3 = .0016\,\pi$$
$$X_4 = .00575\,\pi$$
$$X_5 = .0256\,\pi$$
$$.0016\pi + .00575\pi + .0256\,\pi = 1$$
$$\pi = 30.2 \text{ lbs./sq. in. abs.}$$

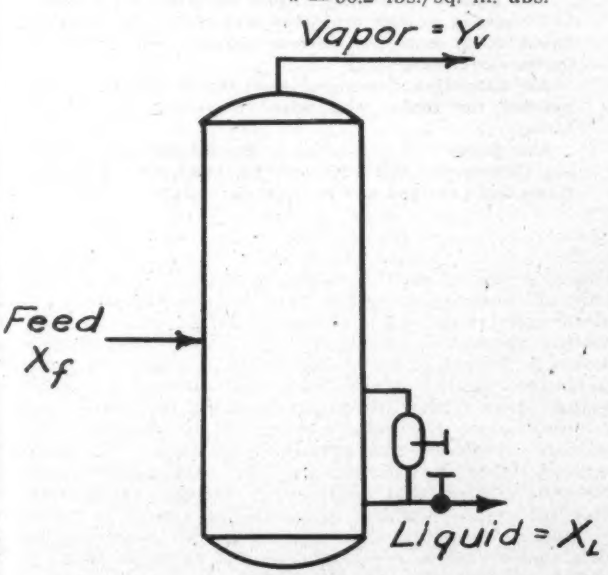

FIGURE 3
A single separator showing incoming feed and outgoing vapor and liquid.

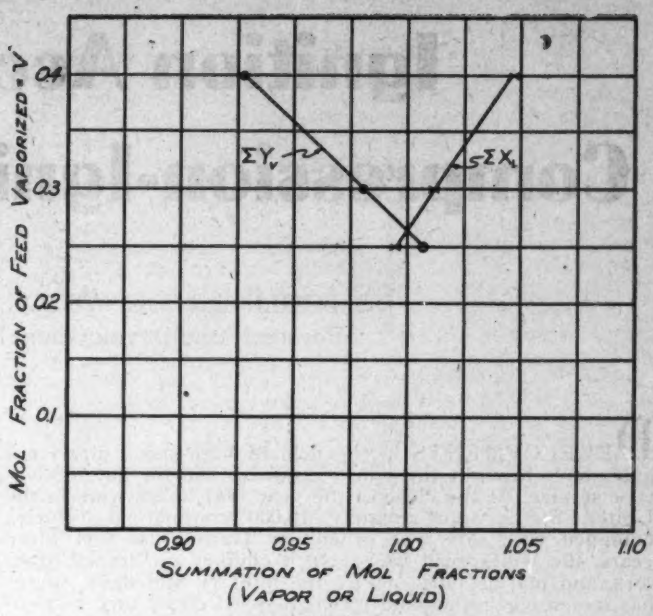

FIGURE 4
Graphical method for simplifying trial and error calculations.

The composition of the drop of liquid in equilibrium with the vapor could be determined by substituting back into equations (10), (11) and (12).

As long as the temperature is maintained at 100° F. there will be partial vaporization at all pressures between 30.2 and 78.25 pounds per square inch, absolute.

If the mixture is subjected to 60 pounds per square inch at 100° F. the fraction vaporized can be calculated by the trial-and-error method by solving equation (5) for each hydrocarbon. See Table at bottom of page.

The number of trials necessary for a solution may be reduced at times by making a graph of three calculations, in which the assumed values of V are plotted against the summation of X_L and Y_v. In Figure 4 such a graph is shown.

Although the trial-and-error method is somewhat laborious, frequent calculations make it possible for an engineer to reduce the required time appreciably. Whenever a large number of components is present in a mixture, approximations can be made by selecting certain key components. In view of the large number of calculations which are being made today on stage separation installations, it is probable that short cuts will be developed which will greatly simplify the work required for obtaining satisfactory solutions.

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[4] Huntington, R. L., Stage Separation of Oil-Gas Mixtures, Science of Petroleum, Oxford Press, London, 1938.
[5] Kimmell, G. O. et al, Stage Separation of Oil-Gas Mixtures, October 17, 1938.
[6] Piromoov and Beiswenger, Equilibrium Vaporization of Oils, etc., A.P.I. Bull. 10, No. 252, 1929.
[7] Rayleigh Equation—Walker, Lewis, McAdams and Gilliland, Principles of Chemical Engineering, Page 532, McGraw Hill Book Company, Inc., 1937.

Let V=0.3 (second trial)				Let V=0.25 (third trial)				Let V=0.26 (fourth trial)			
$V\frac{P-1}{\pi}$	$1+V\left[\frac{P-1}{\pi}\right]$	X_L	Y_v	$V\left[\frac{P-1}{\pi}\right]$	$1+V\left[\frac{P-1}{\pi}\right]$	X_L	Y_v	$V\left[\frac{P-1}{\pi}\right]$	$1+V\left[\frac{P-1}{\pi}\right]$	X_L	Y_v
.633	1.633	.1840	.5740	.5275	1.5275	.197	.613	0.5500	1.5500	.1935	.6030
—.039	.961	.3130	.2720	—.0217	.9783	.307	.267	—0.0338	0.9662	.3110	.2700
—.222	.778	.5150	.1340	—.1850	.8150	.490	.127	—0.1920	0.8080	.4960	.1290
.....	....	1.0120	.9800	.....	.....	.994	1.007	.....	....	1.0005	1.0020

(Within the accuracy of the slide rule and other readings).

Ignition Accelerators for Compression-Ignition Engine Fuels

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Research and Development Laboratories, Riverside, Illinois

THIS paper gives in detail the cetane number improvement that may be expected when ethyl nitrate, isoamyl nitrate, commercial amyl ntirate and acetone peroxide are added to straight-run and cracked diesel fuels from Pennsylvania, Mid-Continent, East and West Texas, and California. Curves are given which show the average cetane number improvement that may be expected when any of the above ignition accelerators are added to typical diesel fuels. The effects of several other ignition accelerators when added to straight-run fuels are shown. Illustrations of the effects of ignition accelerators on the physical properties of diesel fuels are given, and it is shown that the most critical physical property is the flash point.

Engine data are given which show that ignition accelerators do not increase combustion chamber depositions despite the increase in the Conradson carbon of doped fuels. It is shown that the engine economy is lowered in direct proportion to the amount of ignition-accelerator added.

It is also pointed out that if extensive use of ignition accelerators is to be made, a study of their corrosive properties under engine operating conditions must be undertaken.

Cost figures for doping various fuels to a requirement of 50-cetane number are given and show a maximum of about 0.12 cents per cetane number per gallon for California stocks.

An extensive literature and patent search is appended for those who wish to pursue the subject further.

This paper was presented at the Annual S.A.E. Meeting, Detroit, Michigan, January 14, 1942, by J. S. Bogen. It has been revised and brought up to date.

DEVELOPMENTS in the field of high-speed diesel engines have brought them into extensive use for automotive-type service. At the close of the year 1941, there were in the United States approximately 10,000 commercial vehicles equipped with this type of engine. During the past three years, the widespread use of such engines for trucks, tractors, and marine purposes by the military and naval forces has increased the demand for high-speed diesel fuel. In general, these engines require a supply of volatile, high-cetane fuel; moreover, this supply should be produced in or near the district where the engines are operated or refueled. In the East, where straight-run paraffinic-type stock is available in quantities, the problem is not serious; but on the West Coast, where the straight-run fuel has an ignition quality below that required by most engines, there is need for a simple solution to the problem of improving this property of the fuel.

In the past, one of the outstanding advantages of the diesel engine has been its ability to operate economically on low-cost fuel. A survey of a number of engine manufacturers has indicated that a rise of 12 percent in diesel fuel cost will offset any advantage of economy which this type of engine may have at the present time. This narrow margin leaves very little opportunity for the application of quality-improving refining processes. Moreover, if distribution costs are to be kept to a minimum, it is necessary to restrict marketing to a single grade of automotive diesel fuel. The refiner's problem becomes very simple when the source of his crude oil is such that a straight-run cut meets the specifications for high-speed diesel fuel. In cases where the refiner is working with non-paraffinic crudes, his problem of meeting a 50-cetane number requirement will range all the way from gaining a few centane numbers to the greater difficulty of raising the rating of his product 20 or more cetane numbers. It is necessary that an economical solution, such as the use of additives, be found for raising the ignition quality a few cetane numbers.

In some localities the refiner who markets diesel fuel may, of necessity, have to produce high-speed diesel fuel from low-centane stock, such as thermal-recycle gasoil or unfavorable crude oils. In cases where the fuel must be improved by 18- to 20-cetane number, either the stock may be blended with high-cetane material or special processes may be used. The effectiveness of solvent refining and hydrogenation for this purpose has been studied by Dryer, Chenicek, Egloff, and Morrell[1]. They have found that fuels of high ignition quality can be prepared by extraction alone or by solvent extraction and doping, but that a pour-point depressant may be required. Also, they state that the high blending values of the extracts suggest their use as blending stocks for tractor fuels. Hydrogenation produces fuels of high ignition quality without loss of fuel or change in physical properties, such as pour point, flash point, and distillation range; but solvent extraction offers greater possibilities since it can be adapted for use on a wide range of stocks irrespective of their sulfur content. In most cases these processes are prohibitive in cost. Under normal circumstances many refiners do not find it advantageous to produce diesel fuel, since they can obtain approximately the same price for burner oil without the necessity of adhering to such strict specifications. In addition, the refiner who supplies diesel fuel usually is called upon to maintain an expensive technical service organization to care for the complaints which often arise from faulty engine usage.

In 1940, the C.F.R. Automotive Diesel Fuels Division Full-Scale Engine Group, working under C. G. A. Rosen's supervision, conducted a series of tests in which the same four fuels were used in seven different makes of engines. In W. G. Ainsley's report[2] on this series of tests, it was shown that with an increase in cetane number of the fuel, exhaust odors and smoke, engine roughness, engine deposits, and starting difficulties all decreased. These relationships are shown in Figure 1. Some engines show a greater sensitivity to ignition quality of the fuel than do others of different design. More recent investigations along the same line serve to substantiate the results reported by Ainsley with one possible exception—that pertaining to smoke. The data were not conclusive at that time and later investigation bears out the stated belief that some other factors overshadow any effect of cetane number in so far as smoke is concerned. In fact, it is known that operation with some high-cetane fuels under certain conditions results in more black smoke in the exhaust than does the use of lower cetane fuels. The conclusion of the group was, that to insure satisfactory operation in all of the high-speed engines included in the series of tests the fuel should have a minimum-cetane number of 47. On the basis of this conclusion, 50-cetane number fuel has been established as a satisfactory minimum requirement for all automotive-type diesel engines in general service.

Combustion in Diesel Engines

The cetane number of a diesel fuel is a good indication of its ignition qualities and of the duration of the delay period between the time of injection and ignition. In general, it is related to the magnitude of cylinder peak pressures and rough running in most high-speed diesel engines.

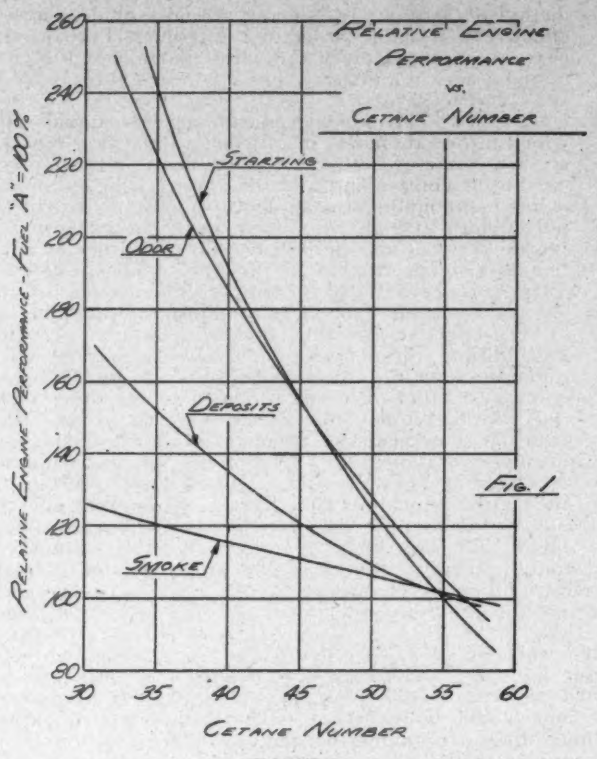

FIGURE 1

The few engines which are not cetane sensitive are those which have combustion chambers designed to avoid high peak pressures even though required to operate on relatively low-cetane fuel. Spontaneous ignition temperature of a fuel is also a factor in its ignition quality. While a low spontaneous ignition temperature is a definite asset for improved ignition quality, there are several other important properties. Boerlage and Broeze have shown that the cracking tendency of a fuel is related to its ignition qualities[3].

The commonly accepted theory that the high peak pressures following a long delay period are due entirely to an accumulation of unburned fuel in the combustion chamber is incorrect. It has been shown by a large number of oscillograms taken with the Rose indicator at the University of Wisconsin[4] that other factors are more important than the quantity of fuel injected before ignition occurs. Two fuels, with ignition qualities of 19-cetane number and 70-cetane number respectively, were injected into an open-combustion chamber engine running at 1250 rpm. The duration of injection was short, about 12 degrees of crank travel, so that in every case all the fuel was injected before any of it started to burn. The delay period was increased by advancing the time of fuel injection. All the fuel was injected during a period of 1.6 milliseconds, but rough running and knocking did not occur until the delay period exceeded 2 milliseconds. The injection timing at which knocking began was 20 B.T.C. (ignition lag 2.04 milliseconds) for the low- and 46° B.T.C. (ignition lag 3.14 milliseconds) for the high-cetane fuel, and the knock intensity increased as injection timing was advanced until violent knocking conditions occurred at a timing of 29° B.T.C. (ignition lag 4.1 milliseconds) for the low- and 54° B.T.C. (ignition lag 4.59 milliseconds) for the high-cetane fuel. This indicates clearly that, the longer a definite quantity of fuel is exposed to the temperature and pressure of the air in the cylinder during the compression stroke, the greater the combustion shock when it finally ignites. Thus, the duration of such exposure is as important as the accumulation of fuel during the delay period.

Therefore one may conclude that pre-flame reactions of the fuel play an important part in determining the rapidity of its combustion.

Means for Controlling Combustion

Inasmuch as it is possible to design diesel engines for operation on low-cetane fuel, there has been much debate as to whether or not there is need for a high-cetane fuel. However, the demands of automotive-engine service are for a reduction in weight and space requirements of the power plant. In general, any attempt to show a saving in fuel because of increased cetane numbers has been disappointing. For engines operating within moderate speed ranges (below 1800 rpm), the thermal efficiency of any given engine stays surprisingly constant for a wide range of fuels. Thus, so far as fuel economy is concerned, the heating value of the fuel is the most important consideration. Simplification of design and reduction in weight per horsepower, together with the expectation of reduced maintenance problems, have lead most high-speed diesel-engine builders to accept the need for fuel with a cetane number of 45 or better. In the past, refiners have been able to meet this demand by proper selection of their products.

It has been pointed out that both the nature of the crude oil and the process of refining affect the ignition qualities of a diesel fuel. Table 1 shows cetane-number ratings for straight-run diesel fuels produced from almost every major oil field in the United States. While these figures undoubtedly are accurate for the particular samples tested, samples will differ somewhat within any given locality. It is interesting to note that about 30 percent of these straight-run fuels are less than 50-cetane number. It has been pointed out by several investigators that high ignition quality, in many cases, is linked up with the presence in the fuel of paraffinic chains[3]. This fact is emphasized by the data in Table 1. The type of crude oil has been defined in terms of the division of the straight-run product among paraffins, naphthenes, and aromatics, in percentages. While these values are approximations from calculations depending upon UOP Characterization Factor[5], they may be regarded as sufficiently accurate for purposes of comparison.

Other means for supplying a fuel of satisfactory combustion characteristics are the use of special processes or the use of additives. The use of special processes has been discussed previously. The remainder of this paper is devoted to a detailed study of diesel fuel ignition accelerators.

Ignition Accelerators

The hundreds of materials that have been proposed as ignition accelerators have been arranged in eleven groups. An extensive literature and patent search has been made and the information classified. A complete bibliography is furnished at the close of this paper. As an introduction to the detailed study of a few of the possible additives, each of the major groups are discussed in the following paragraphs.

A. Aliphatic hydrocarbons—Examples of this class of ignition accelerators are acetylene, allylene, divinylacetylene and butadiene. These compounds are relatively ineffective as ignition promoters when compared with the nitrates and peroxides, and consequently must be added in reasonably large concentrations. The mechanism of the reaction appears to be oxidation of the olefinic double

TABLE 1

Cetane Numbers for Straight Run Diesel Fuels from United States Crude Sources Arranged Geographically

CRUDE SOURCE	TYPE OF CRUDE*			Cetane No.	REFERENCE†	
	P	N	A		No.	Table No.
1. Pennsylvania	85	9	6	65	12	IV
2. Pennsylvania	85	9	6	62	11	I
3. Kentucky	73	12	15	52	11	II
4. Michigan	83	9	8	68	11	II
5. Michigan	66	15	19	56	12	IV
6. Indiana	74	12	14	52	12	IV
7. Illinois	74	12	14	52	12	IV
8. Mid-Continent	75	12	13	55	12	III
9. Kansas	69	14	17	59	12	IV
10. Oklahoma	75	12	13	56	11	II
11. Louisiana	89	7	4	63	12	IV
12. Gulf Coast	75	12	13	58	11	II
13. South Texas	47	21	32	33	12	III
14. South Texas	45	22	33	32	12	IV
15. East Texas	75	12	13	55	11	II
16. East Texas	70	14	16	57	12	IV
17. West Texas	83	9	8	64	12	IV
18. West Texas	69	14	17	48	12	IV
19. West Texas	67	15	18	45	11	II
20. New Mexico	58	17	25	48	12	IV
21. Rocky Mountain	73	12	15	51	11	II
22. Wyoming	80	10	10	68	12	IV
23. Wyoming	73	12	15	59	12	IV
24. California	69	14	17	47	11	II
25. California	64	16	20	45	12	III
26. California	56	18	26	41	12	IV

* The type of crude is defined by stating the approximate amounts of the different types of hydrocarbons in the straight run diesel fuel, as indicated by laboratory data and UOP Characterization Factor. (5)
P—Paraffins, in percent. N—Naphthenes, in percent. A—Aromatics, in percent.
† The data for this table were taken from the references No. 11 and No. 12.

bond, which produces sufficient thermal energy to cause ignition. (16 references.)

B. *Aldehydes, ketones, ether, esters, etc.*—These compounds may be exemplified by furfuraldehyde, acetone, diethyl ether, ethyl acetate, nitroglycerine and methyl alcohol. They have an order of effectiveness slightly greater than that of the aliphatic hydrocarbons; however, diethyl ether is excellent for starting, whereas the other compounds are not. The most logical explanation of the mechanism of the operation seems to be that under engine operating conditions this type of compound is thermally unstable and therefore may be readily ignited. Nitroglycerine, being an explosive, is very unstable under temperaure and pressure. (61 references.)

C. *Metal derivatives*—Some examples of this group are barium nitrate, copper oleate, manganese dioxide, potassium chlorate, and vanadium pentoxide. In general, the effectiveness of the compounds is just slightly less than that of the aliphatic hydrocarbons and the peroxides. Some are the ingredients of explosives, e.g., potassium chlorate. The pentoxides, e.g., vanadium pentoxide, apparently have a dual effect, that of the metal and that of the oxygen, and they are unstable under engine operating conditions. The exact action of the metals is not understood and, like the action of tetraethyl lead in the Otto cycle, is subject to many explanations. (29 references)

D. *Alkyl nitrates and nitrites and nitro compounds*—Typical of this group are ethyl nitrate and ethyl nitrite. This class of compounds is highly effective in promoting ignition in the diesel engine, being exceeded only by certain of the peroxides. Ignition is apparently caused by the action of the nitrate or nitrite group. These compounds are semiexplosives. (92 references)

E. *Aromatic nitro compounds*—These may be exemplified by nitrobenzene or nitronaphthalene. Their action is essentially the same, but they are less effective than the alkyl nitrates because of the stability of the aromatic ring. (42 references)

F. *Nitration*—Nitration of the fuel produces many compounds to which the nitrate group is attached. In general, they are less effective than the alkyl nitrates because of the lower ratios of the weights of the nitrate group to those of the hydrocarbon portion of the compound. However, the action is similar. (9 references)

G. *Oximes and nitroso compounds*—Examples of this group are formaldoxime and nitrosomethylurethane. In general, these compounds have an effectiveness approximately halfway between that of the aliphatic hydrocarbons and alkyl nitrates. Again, the effectiveness is due to thermal instability and the action of the nitroso group. In other words, they are good oxidizing agents. (4 references)

H. *Oxidation and oxidation products*—Oxygen and ozone are two typical examples of the class of materials included in this section. Their effectiveness is relatively low and their action is explained by the fact that the rate of oxidation is increased by the greater concentration of oxygen. (28 references)

I. *Peroxides*—Acetone peroxide is the most prominent example of the peroxide class. It is slightly more effective than the alkyl nitrates, and therefore heads the list so far as effectiveness is concerned. These compounds are of an explosive nature and are effective because of their extreme instability. (49 references).

J. *Polysulfides*—A representative of the polysulfide group is diethyl tetrasulfide. In general, the polysulfides have an effectiveness on the order of the oximes. Perhaps this is to be expected, since the sulfur portion of the compound reacts in a manner similar to oxygen compounds. (22 references)

K. *Unclassified*—This section includes various materials upon which information was insufficient to justify a separate section. Some of these are the halogens, sulfur and certain sulfur compounds, and the amines. The sulfur and sulfur compounds have an action similar to that of the polysulfides and all compounds with the exception of the thionitrates and thionitrites have an order of effectiveness similar to that of the polysulfides. The thionitrates and thionitrites, along with certain of the chloronitro compounds, e.g., trichloronitromethane, are so very effective that they rank with acetone peroxide. In addition, these compounds have a marked effect upon the starting characteristics of the fuel which is contrary to that observed for most of the other materials. Although not considered practical at this time, chlorine is exceedingly effective for both starting and normal operation. The action of the amines as ignition accelerators is exceedingly questionable. Certain of them in combination with nitroso groups are effective but amines as such, e.g., aniline, are definite anti-knock agents for the Otto cycle engine. (86 references).

A rough generalization in regard to the solubility of the various ignition accelerators may be made, i.e., the more effective the ignition accelerator, the less soluble in diesel fuel.

It is surprising to find a number of compounds mentioned in the literature and patent search which, according to accepted theories, could have but little of the desired effect and would be expected to have the opposite effect. Among these are aniline, benzene, iron pentacarbonyl, and ammonia, all of which are known to have anti-knock properties when used in the spark-ignition engine. Consequently, a certain amount of caution must be exercised in the use of this literature search. Since an attempt was made to have the search as nearly complete as possible, nothing was omitted even though some of the material is of doubtful value, and 303 references are included in the 11 sections. They are cross-indexed both as to compound type and general classification. It is interesting to note that the sections may be listed in the following order of their prominence, as shown by the number of individual references in each section:

D. Alkyl nitrates and nitrites—92
B. Aldehydes, ketones, ethers, esters, etc.—61
I. Peroxides—49
E. Aromatic nitro compounds—42
C. Metal derivatives—29
H. Oxidation and oxidation products—28
J. Polysulfides—22
A. Aliphatic hydrocarbons—16
F. Nitration—9
G. Oximes and nitroso compounds—4.

The fact that the alkyl nitrate and nitrite section shows the most references probably explains why these compounds have most nearly approached commercial development.

It should also be noted that the statements as to the effectiveness of the various classes are based on values obtained by this laboratory and it is realized that they do not agree completely with some of the previously published results.

Tables 2 and 3 show the comparative effectiveness of some of these additives when applied to a given fuel. Table 2 is for a 50-cetane fuel and Table 3 is for a 44-cetane fuel.

TABLE 2

EFFECT OF VARIOUS IGNITION ACCELERATORS

Cetane Number of a Mid-Continent Straight-Run Diesel Fuel to Which Has Been Added 2% by Weight of the Following Compounds

COMPOUND	Cetane No.
Mid-Continent straight run (undoped)	50
Tetrabromethane	50
Normal butyl bromide	50
p-Aminodimethylaniline	43
Amylamine	50
Copper oleate	50
Nitrobenzene	50
Trinitrotoluene	52
Benzoyl peroxide	59
Acetone peroxide (Table V)	76
Nitromethane (insoluble)	..
Ethyl nitrate (Table 5)	67
Isoamyl nitrate (Table 5)	69

TABLE 3

CETANE IMPROVEMENT FOR VARIOUS ALKYL NITRATES

When 1.5% Is Added to a Base Fuel of 44 Cetane Number

ALKYL NITRATE	Cetane Number—Base Fuel Plus 1.5% Alkyl Nitrate	Increase in Cetane Number
Mixed amyl nitrates	63	19
Normal amyl nitrate	67	23
Normal butyl nitrate	63	19
Isopropyl nitrate	61	17
Octyl nitrate	63	19
Cyclohexyl nitrate	66	22
Secondary hexyl nitrate	62	18
Secondary amyl nitrate	64	20
Isoamyl nitrate	65	21
Normal hexyl nitrate	64	20

Note: The data for this table were furnished in private communication from Sharples Chemicals, Inc., Philadelphia, Pennsylvania. (January, 1941).

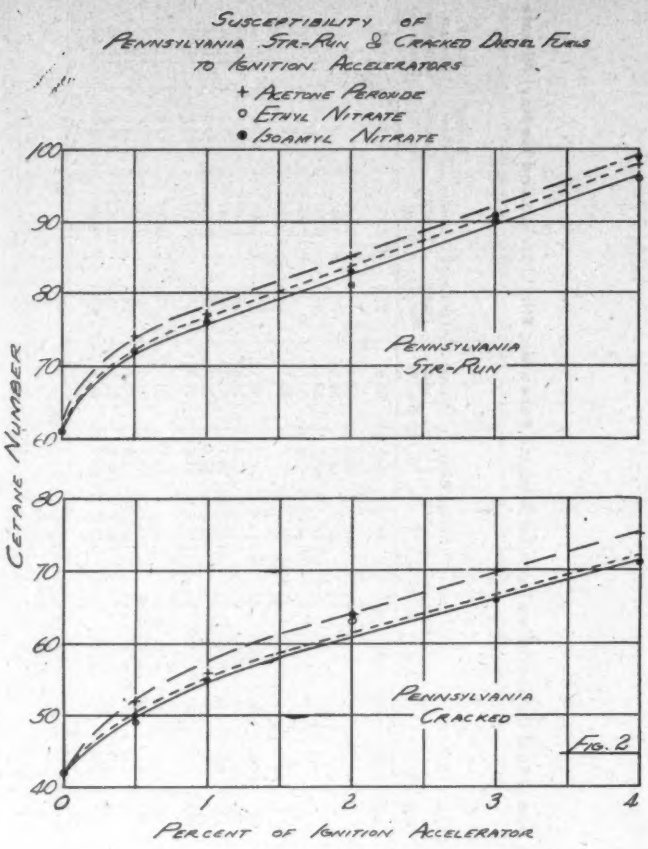

FIGURE 2

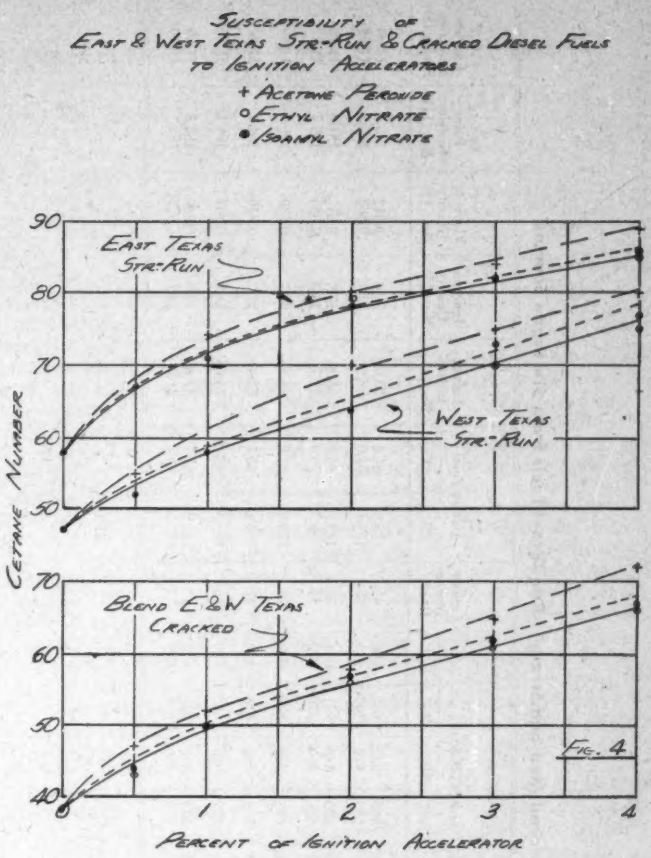

FIGURE 4

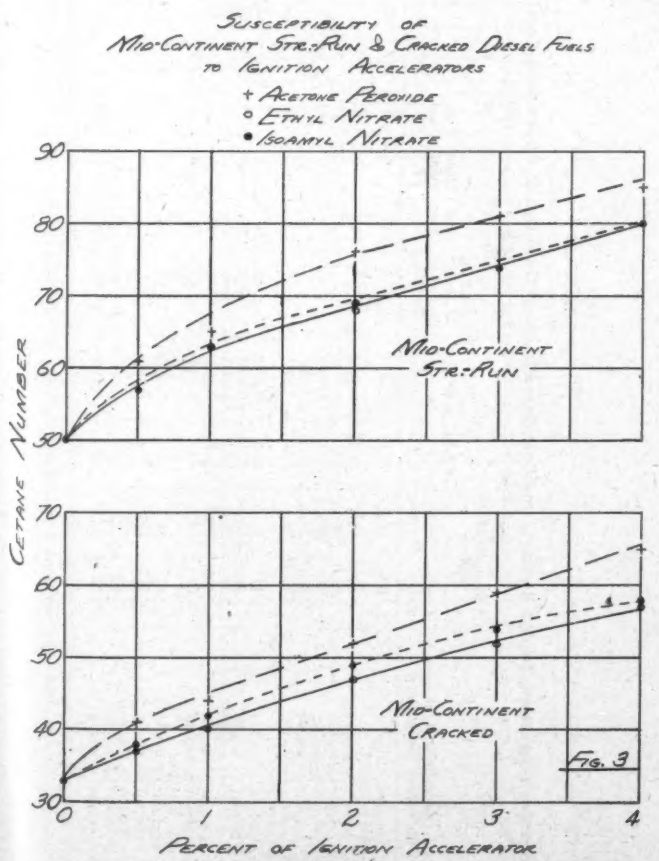

FIGURE 3

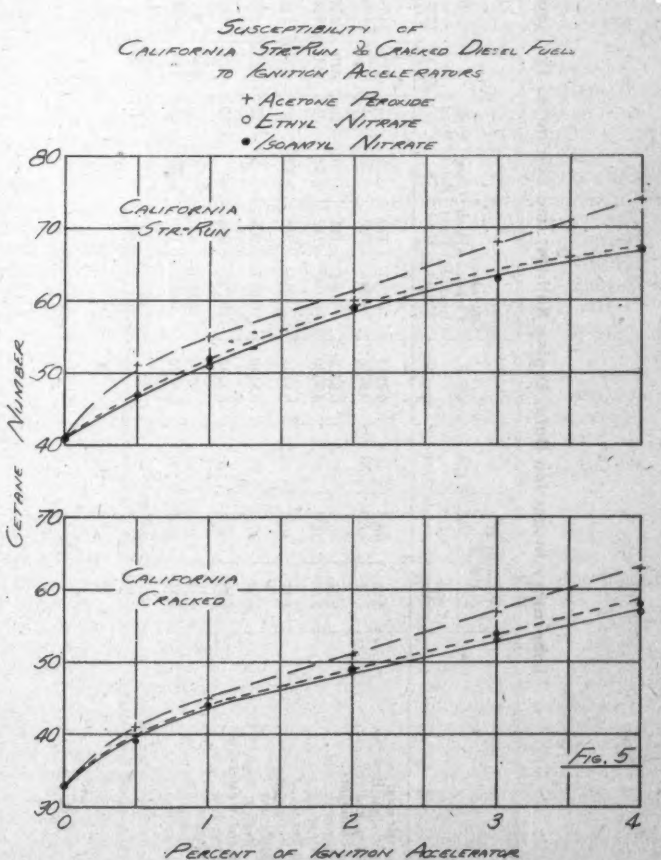

FIGURE 5

TABLE 4

Laboratory Inspection Data, Engine Ratings, and Calculated Ignition Qualities of Cracked Mud and Straight-Run Diesel Fuels from Six Crude Sources

FUELS	Viscosity at 100° F.		Gravity at 60° F.		Conradson Carbon Percent by Weight	Flash Point °F.	Cloud Point °F.	Pour Point °F.	DISTILLATION CHARACTERISTICS, °F.									Cetane Number Delay	Aniline Point		Diesel Index No. (11)	Ignition Quality No. (13)	Viscosity Gravity No. (11)	Boiling Point Gravity No. (11)	U.O.P. Characterisation Factor (5)
	Centistokes	S.U.* Seconds	°A.P.I.	Specific					I.B.P.	10%	20%	30%	50%	70%	90%	95%	E.P.		°F.	°C.					
1. Pennsylvania:																									
a. Straight Run	3.25	38.2	40.8	0.8212	0.020	170	25	15	372	461	490	508	538	568	623	652	668	61	178.9	81.6	73.0	39.3	0.812	173.1	12.06
b. Cracked	3.31	37.6	30.1	0.8756	0.021	180	20	5	323	480	498	512	540	569	613	633	646	42	131.7	54.8	39.6	21.4	0.868	188.9	11.38
2. Mid-Continent:																									
a. Straight Run	2.48	35.4	37.5	0.8373	0.004	145	— 5	20	340	432	450	463	500	525	580	601	631	50	148.7	64.8	55.8	27.9	0.837	181.6	11.70
b. Cracked	2.56	35.6	28.2	0.8860	0.140	182	—30	—35	400	448	458	466	482	501	566	620	620	33	98.2	36.8	27.7	13.3	0.885	196.7	11.07
3. East Texas:																									
a. Straight Run	4.17	40.0	36.2	0.8438	0.010	240	30	20	488	518	530	538	554	578	616	638	660	58	170.8	77.2	61.8	34.3	0.839	179.5	11.89
4. West Texas:																									
a. Straight Run	3.38	37.8	34.2	0.8540	0.090	205	— 5	—25	410	480	497	508	528	552	593	618	638	47	150.4	65.7	51.4	27.2	0.846	184.1	11.63
5. East and West Texas:																									
a. Cracked	2.84	36.3	30.3	0.8745	0.097	265	—	10	370	419	444	464	510	572	635	650	650	38	118.8	48.2	36.0	18.4	0.862	191.1	11.26
6. California:																									
a. Straight Run	3.74	38.8	33.5	0.8576	0.050	170	5	0	378	437	457	474	510	552	610	642	676	41	142.0	61.1	37.6	19.2	0.847	186.5	11.25
b. Cracked	2.44	35.3	30.7	0.8724	0.070	185	—25	—35	416	435	445	452	471	499	566	616	628	33	101.5	44.2	31.2	14.7	0.872	194.1	11.19

*These values were obtained by conversion from kinematic viscosities (centistokes at 100° F.)

TABLE 5

Laboratory Inspection, Engine Ratings, and Calculated Ignition Qualities of Doped Mid-Continent Straight-Run Diesel Fuel Comparative Data for Acetone Peroxide, Ethyl Nitrate and Isoamyl Nitrate

Mid-Continent Straight Run With Various Diesel Dopes	Viscosity at 100° F.		Gravity at 60° F.		Conradson Carbon Percent by Weight	Flash Point °F.	Cloud Point °F.	Pour Point °F.	DISTILLATION CHARACTERISTICS, °F.									Cetane Number Delay	Aniline Point		Diesel Index No. (11)	Ignition Quality No. (13)	Viscosity Gravity No. (11)	Boiling Point Gravity No. (11)	U.O.P. Characterisation Factor (5)
	Centistokes	S.U.* Seconds	°A.P.I.	Specific					I.B.P.	10%	20%	30%	50%	70%	90%	95%	E.P.		°F.	°C.					
1. Without Diesel Dope	2.48	35.4	37.5	0.8373	0.004	145	— 5	—20	340	432	450	463	500	525	580	601	631	50	148.7	64.8	55.8	27.9	0.837	181.6	11.70
2. Acetone Peroxide:																									
0.5 percent by weight	2.49	35.4	37.1	0.8393	.....	....	— 5	—10	....	....	....	....	....	....	....	....	....	61	148.1	54.5	54.8	....	0.839	....	....
1.0 percent by weight	2.48	35.4	37.0	0.8398	.....	....	— 5	—15	....	....	....	....	....	....	....	....	....	65	147.2	64.0	54.5	....	0.839	....	....
2.0 percent by weight	2.48	35.4	36.6	0.8418	.....	....	— 5	—20	....	....	....	....	....	....	....	....	....	76	146.1	63.4	53.5	....	0.841	....	....
3.0 percent by weight	2.50	35.4	36.2	0.8438	.....	....	—10	—20	....	....	....	....	....	....	....	....	....	81	145.4	63.0	52.6	....	0.043	....	....
4.0 percent by weight	2.49	35.4	36.0	0.8448	.....	....	—10	—20	....	....	....	....	....	....	....	....	....	85	144.7	62.6	52.1	....	0.844	....	....
3. Ethyl Nitrate:																									
0.5 percent by weight	2.44	35.3	37.3	0.8383	0.040	130	— 5	—15	210	432	448	464	491	527	580	603	628	57	147.8	64.3	55.1	27.1	0.838	182.6	11.70
1.0 percent by weight	2.41	35.2	37.1	0.8393	0.080	120	—10	—15	216	427	446	461	489	525	577	604	630	63	147.1	53.9	54.6	26.7	0.839	183.1	11.67
2.0 percent by weight	2.34	35.0	36.7	0.8413	0.090	100	— 5	—10	198	426	446	452	492	527	579	606	628	67	145.7	53.1	53.5	26.3	0.842	183.4	11.65
3.0 percent by weight	2.27	34.8	36.5	0.8423	0.110	95	—10	—15	198	425	442	462	492	524	576	603	625	75	144.4	52.4	52.7	25.9	0.844	183.7	11.63
4.0 percent by weight	2.22	34.7	36.1	0.8445	0.130	95	—10	—20	202	420	445	460	488	524	578	602	622	80	143.1	61.7	51.5	25.1	0.847	184.8	11.59
4. Isoamyl Nitrate:																									
0.5 percent by weight	2.45	35.3	37.2	0.8388	0.070	140	— 5	—10	315	427	446	462	493	525	580	606	618	57	147.6	54.2	54.9	27.1	0.838	182.6	11.68
1.0 percent by weight	2.44	35.3	37.2	0.8388	0.100	140	—10	—25	263	429	449	463	491	525	580	608	620	63	146.9	63.8	54.6	26.8	0.838	182.8	11.68
2.0 percent by weight	2.37	35.1	36.9	0.8403	0.180	130	—10	—15	215	422	441	456	486	520	574	601	615	69	145.3	62.9	53.6	26.1	0.841	183.6	11.64
3.0 percent by weight	2.34	35.0	36.7	0.8413	0.210	130	—10	—15	235	416	442	458	486	522	577	602	618	74	143.5	61.9	52.7	25.6	0.842	183.9	11.62
4.0 percent by weight	2.32	34.9	36.4	0.8428	0.250	130	— 5	—15	234	384	441	458	487	522	579	606	615	80	141.9	61.0	51.7	25.2	0.844	184.3	11.56

* These values were obtained by conversion from kinematic viscosities (centistokes at 100° F.)

TABLE 6

Laboratory Inspection Data, Engine Ratings, and Calculated Ignition Qualities of Doped Mid-Continent Cracked Diesel Fuel

Comparative Data for Acetone Peroxide, Ethyl Nitrate and Isoamyl Nitrate

Mid-Continent Cracked With Various Diesel Dopes	Viscosity at 100° F.		Gravity at 60° F.		Conradson Carbon Percent by Weight	Flash Point °F.	Cloud Point °F.	Pour Point °F.	DISTILLATION CHARACTERISTICS, °F.							Cetane Number Delay	Aniline Point		Diesel Index No. (11)	Ignition Quality No. (13)	Viscosity Gravity No. (11)	Boiling Point Gravity No. (11)	U.O.P. Characterization Factor (S)
	Centistokes	S.U. Seconds	°A.P.I.	Specific					I.B.P.	10%	20%	30%	50%	70%	90%	95%	E.P.		°F.	°C.					
1. Without Diesel Dope	2.56	35.6	28.1	0.8866	0.14	182	—30	—35	400	448	458	466	482	501	566	620	620	33	98.2	36.8	27.7	13.3	0.895	196.7	11.07
2. Acetone Peroxide:																									
0.5 percent by weight	2.57	35.6	27.9	0.8877	.....	...	—20	—35	....	....	....	....	....	....	....	....	....	41	96.8	36.0	27.0	....	0.896	....	....
1.0 percent by weight	2.57	35.6	27.9	0.8877	.....	...	—30	—35	....	....	....	....	....	....	....	....	....	44	96.1	35.6	26.8	....	0.897	....	....
2.0 percent by weight	2.58	35.6	27.7	0.8888	.....	...	—30	—35	....	....	....	....	....	....	....	....	....	52	94.8	34.9	26.3	....	0.898	....	....
3.0 percent by weight	2.59	35.7	27.3	0.8916	.....	...	—10	—35	....	....	....	....	....	....	....	....	....	59	93.9	34.4	25.6	....	0.900	....	....
4.0 percent by weight	2.60	35.7	27.0	0.8927	.....	...	—30	—35	....	....	....	....	....	....	....	....	....	65	93.2	34.0	25.2	....	0.901	....	....
3. Ethyl Nitrate:																									
0.5 percent by weight	2.53	35.5	28.0	0.8871	0.24	165	—30	—35	266	447	458	466	483	506	556	600	604	37	95.2	35.1	26.7	12.9	0.896	196.8	11.04
1.0 percent by weight	2.50	35.4	27.8	0.8883	0.33	155	—30	—35	192	449	460	467	482	505	555	597	602	40	94.6	34.8	26.3	12.7	0.897	197.2	11.03
2.0 percent by weight	2.43	35.2	27.6	0.8894	0.40	140	—30	—35	193	447	458	466	484	505	556	596	600	47	93.7	34.3	25.9	12.5	0.899	197.3	11.01
3.0 percent by weight	2.33	34.9	27.3	0.8911	0.45	130	—30	—35	206	444	458	466	481	505	556	595	598	52	93.2	34.0	25.4	12.2	0.902	198.1	11.11
4.0 percent by weight	2.26	34.8	27.0	0.8927	0.50	115	—20	—35	190	442	458	466	482	504	556	598	604	56	92.7	33.8	25.0	12.1	0.904	198.4	10.97
4. Isoamyl Nitrate:																									
0.5 percent by weight	2.54	35.5	28.1	0.8866	0.24	180	—30	—35	286	451	460	470	485	505	559	595	612	38	95.2	35.1	26.8	13.0	0.895	196.5	11.06
1.0 percent by weight	2.52	35.5	28.0	0.8871	0.33	170	—30	—35	272	454	460	468	484	505	553	586	591	42	94.5	34.7	26.5	12.8	096.8	11.05
2.0 percent by weight	2.48	35.4	27.7	0.8888	0.41	170	—10	—35	274	444	458	467	483	504	555	590	592	49	93.2	34.0	25.8	12.5	0.898	197.3	11.02
3.0 percent by weight	2.44	35.3	27.6	0.8894	0.48	165	—30	—35	238	441	458	467	482	504	559	596	610	54	91.8	33.2	25.3	12.2	0.899	197.5	11.00
4.0 percent by weight	2.40	35.2	27.2	0.8916	0.55	160	—35	—35	247	413	455	467	484	506	562	588	604	60	90.7	32.6	24.7	11.9	0.902	197.9	10.95

* These values were obtained by conversion from kinematic viscosities (centistokes at 100° F.)

Comparative Study of Three Prominent Ignition Accelerators

The effects upon cetane number of three different ignition accelerators, i.e., ethyl nitrate, isomyl nitrate, and acetone peroxide when they are added to four types of straight-run and cracked stocks, are shown in Figures 2 through 6 and in Tables 4 through 9. Inspection of the data indicates that these three types of ignition accelerators raise the cetane number of the stocks to which they are added in the order of ascending effectiveness listed below:

Ethyl nitrate
Commercial amyl nitrate
Isoamyl nitrate
Acetone peroxide.

In general, fuels of high-cetane number are more responsive to additions of ignition accelerators than those of low-cetane number. This agrees with the findings of Broeze and Hinze.[8] This is the opposite effect from that usually noted when tetraethyl lead is added to gasoline, since the lead susceptibility of most gasolines decreases as the octane number rises. The data in the previous curves are summarized as shown in Figures 7, 8, 9, and in Table 8. These susceptibility charts are useful in predicting the rise in ignition quality owing to the addition of ignition accelerators to fuels whose clear cetane number is known. If exact values are needed on the susceptibility of a fuel to the addition of any type of additive, it is necessary that engine determinations be made. The susceptibility of fuels to additives is different in various engines; for example, when ethyl nitrate is added to a fuel and is run in both a CFR diesel engine, by the Delay Method, and in the submarine-type Fairbanks-Morse engine, 5 percent of ethyl nitrate increases the ignition quality an average of 38-cetane numbers in the submarine engine and only 19 in the CFR engine.

The effect of ignition accelerators on physical properties of diesel fuels is clearly shown in Figures 10 through 13 and Tables 5 and 6. The most pronounced effect of the additives is on the flash point and Conradson carbon figures. The data on the flash point are shown in Figure 10 and Tables 5 and 6. The reduction in flash point, for all but isoamyl nitrate, is of such magnitude as to cause the usual light diesel fuel to fall below the 150° F. legal flash point. We know of no method of circumventing this serious obstacle except to have the initial boiling and flash points of the fuel high enough to stand the reduction caused by the additive. If the 90-percent and end-point specifications are to be met, the diesel fuel will have to be a rather narrow cut of the total possible fraction of crude which might ordinarily be used. The increase in the Conradson carbon figures is shown in Tables 5 and 6. The inspection data indicate that the Conradson carbon increase, whether taken on the complete fuel or on the 10-percent-distillation bottoms, is of sufficient magnitude to cause serious engine deposits. However, all engine experience known to the authors indicates that deposits using doped fuels are no more serious than those obtained with clear fuels whose Conradson carbon on the 10-percent bottoms is equal to the Conradson carbon of the doped fuel before the addition of the ignition accelerator. It is also interesting to observe that the increase in Conradson carbon with the addition of dope is more marked in cracked fuels; this is to be expected when the chemistry of ignition accelerators is considered.

All data known up to the present indicate that acetone peroxide probably is the most effective, reasonably stable ignition accelerator, and commercial amyl nitrate is the most effective semi-commercially available ignition accelerator.

Isoamyl Nitrate

Amyl nitrate is the only accelerator whose cost is reasonable and for which commercial production has been set up tentatively. Sharples Chemicals, Inc., has quoted a price of $1.00 per gallon for commercial amyl nitrate. This material is slightly less effective than the pure isoamyl nitrate, for which a large amount of data is given in the previously discussed curves and tables. Its effectiveness is also very little different from that of ethyl nitrate. A number of investigators, ourselves included, have found that commercial amyl nitrate is stable in storage either when blended with a fuel or in the concentrated form. Fuel blends stored for over three years have shown no drop in cetane number or change in other properties due to the addition of the commercial amyl nitrate. The effect of various isomeric alkyl nitrate is shown in Table 3.

Table 10 indicates the cost of increasing the ignition quality of various fuels, both straight-run and recycle stock, with commercial amyl nitrate. It is interesting to note that the peak cost for a California cracked stock amounts to approximately $0.0012 per cetane number per gallon, or

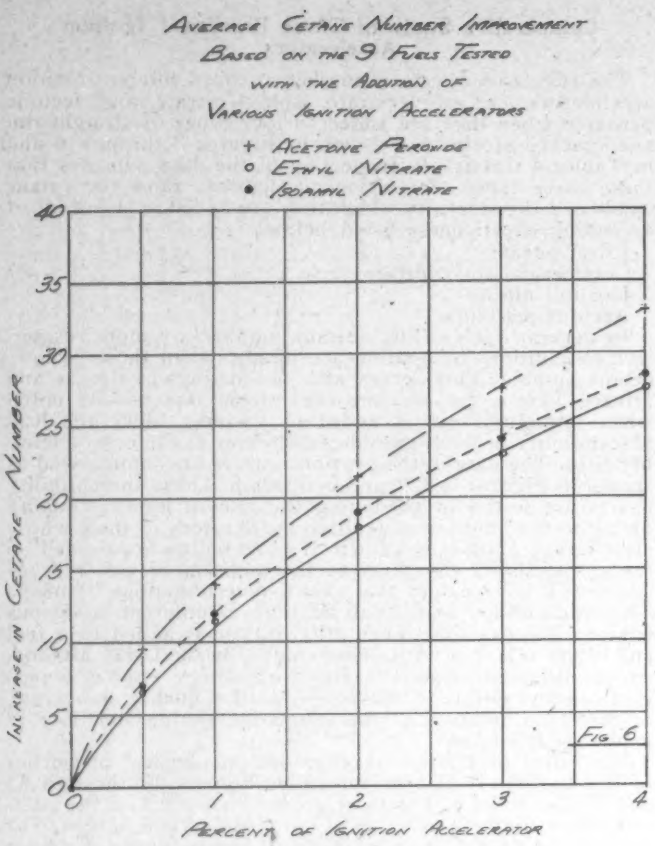

FIGURE 6

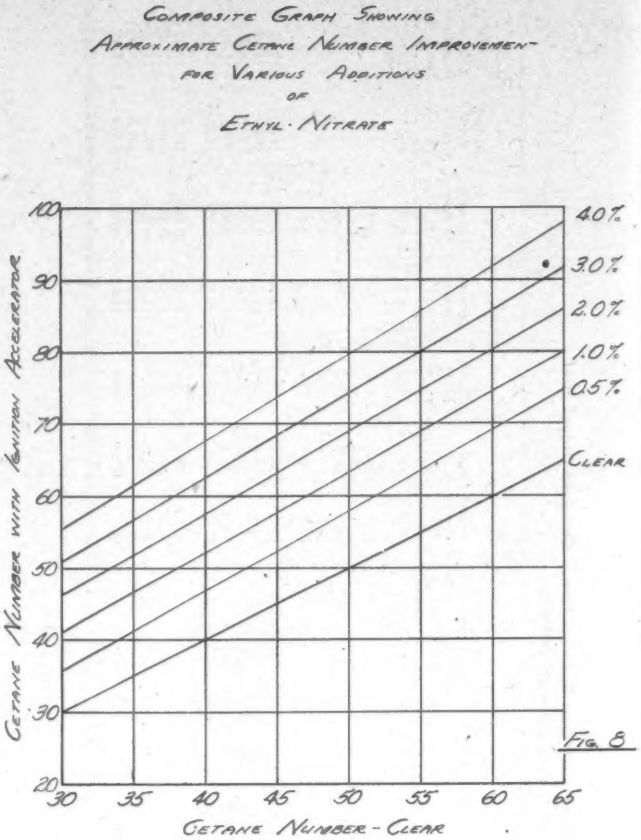

FIGURE 8

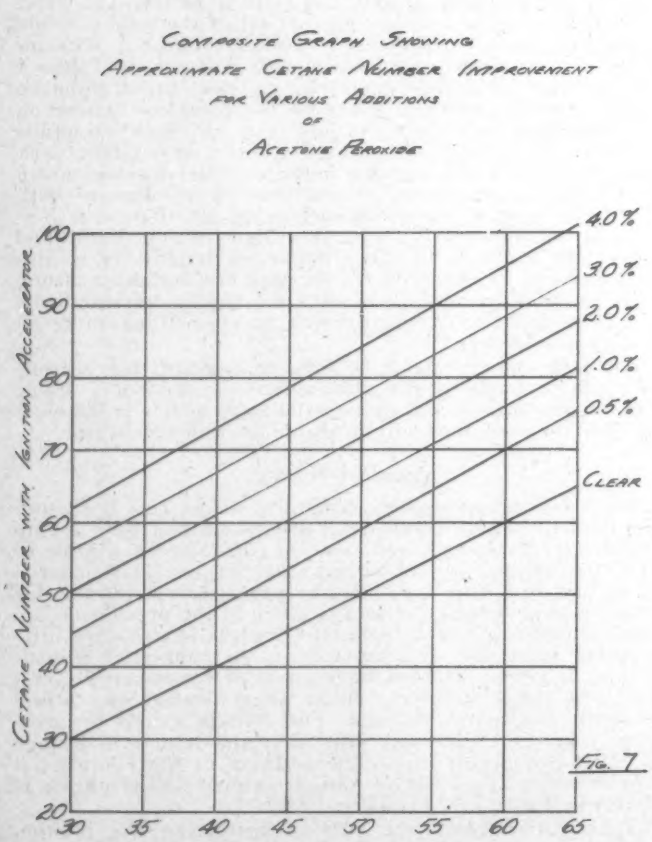

FIGURE 7

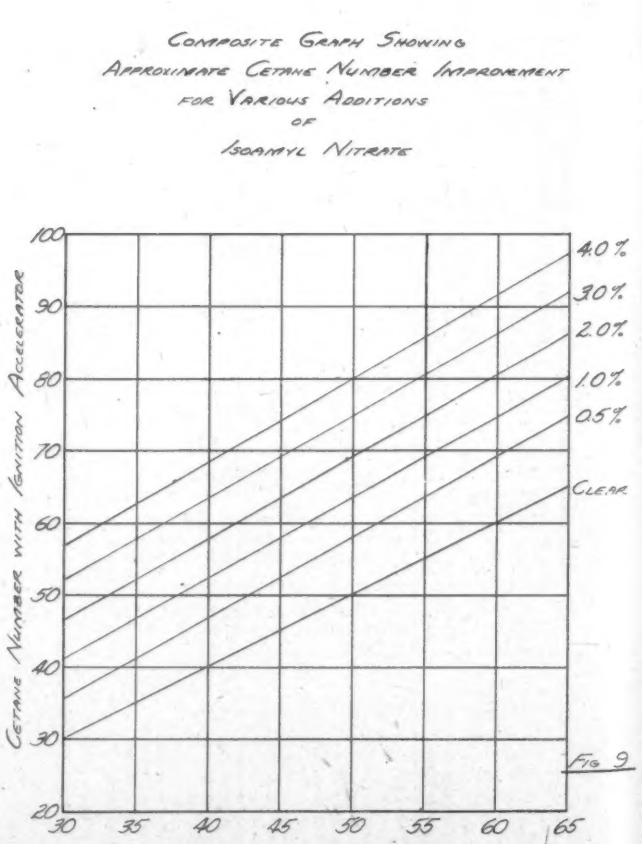

FIGURE 9

TABLE 7

Comparative Data for Three Dopes When Added to Straight-run and Cracked Diesel Fuels from Six Crude Sources. Acetone Peroxide, Ethyl Nitrate, Isoamyl Nitrate

FUEL	DOPE	Un-doped	CETANE NUMBERS 0.5%	1.0%	2.0%	3.0%	4.0%
1. Pennsylvania:							
a. Straight run	Acetone Peroxide	61	74	77	85	91	98
	Ethyl Nitrate	61	72	76	81	91	99
	Isoamyl Nitrate	61	72	76	83	90	96
b. Cracked	Acetone Peroxide	42	52	56	64	70	75
	Ethyl Nitrate	42	49	55	63	66	71
	Isoamyl Nitrate	42	50	56	64	66	71
2. Mid-Continent:							
a. Straight run	Acetone Peroxide	50	61	65	76	81	85
	Ethyl Nitrate	50	57	63	68	75	80
	Isoamyl Nitrate	50	57	63	69	74	80
b. Cracked	Acetone Peroxide	33	41	44	52	59	65
	Ethyl Nitrate	33	37	40	47	52	57
	Isoamyl Nitrate	33	38	42	49	54	58
3. East Texas:							
a. Straight run	Acetone Peroxide	58	67	74	80	84	89
	Ethyl Nitrate	58	67	71	79	82	85
	Isoamyl Nitrate	58	67	71	78	82	86
4. West Texas:							
a. Straight run	Acetone Peroxide	47	55	59	70	75	80
	Ethyl Nitrate	47	52	58	64	70	75
	Isoamyl Nitrate	47	52	58	64	73	77
5. East & West Texas:							
a. Cracked	Acetone Peroxide	38	47	52	58	65	72
	Ethyl Nitrate	38	43	50	56	61	66
	Isoamyl Nitrate	38	44	50	57	62	67
6. California:							
a. Straight run	Acetone Peroxide	41	51	55	60	68	74
	Ethyl Nitrate	41	47	51	59	63	67
	Isoamyl Nitrate	41	47	52	59	63	67
b. Cracked	Acetone Peroxide	33	41	45	51	57	63
	Ethyl Nitrate	33	39	44	49	53	57
	Isoamyl Nitrate	33	39	44	49	54	58

TABLE 8

Average Cetane Number Improvement With Addition of Three Diesel Dopes to the Nine Fuels Listed in Table 4

Averages from data of Table 7

DIESEL DOPE	Average Increase in Cetane Number for Dope Additions 0.5 Percent	1.0 Percent	2.0 Percent	3.0 Percent	4.0 Percent
Acetone peroxide	9.6	13.8	21.4	27.7	33.1
Ethyl nitrate	6.7	11.7	18.1	23.3	27.7
Isoamyl nitrate	7.0	12.1	18.8	24.0	28.6

TABLE 9

Amount of Dope Required to Raise the Fuels Listed in Table 4 to 50-Cetane Number

Percent of dope by weight

CRUDE SOURCE	CRACKED Mid-Cont.	Cal.	E. & W. Texas	Penn.	Straight Run Cal.	W. Tex.
Cetane Number	33	33	38	42	41	47
Acetone peroxide, percent	1.70	1.80	0.80	0.40	0.50	0.15
Ethyl nitrate, percent	2.40	2.33	1.10	0.55	0.80	0.30
Isoamyl nitrate, percent	2.20	2.25	1.00	0.50	0.75	0.20

TABLE 10

Cost of Increasing Ignition Quality to 50-Cetane Number with Commercial Amyl Nitrate for Cracked and Straight-Run Distillates from Five Crude Oils

FUEL	Penn. Cracked	Mid-Cont. Cracked	CALIFORNIA Str.-R.	Cracked	W. Tex. Str.-R.	E. & W. Tex. Cracked
Cetane number	42	33	41	33	47	38
Dope required to equal 50-cetane number, percent by weight	0.50	2.20	0.75	2.25	0.20	1.00
Increase in cost by adding dope, cents per gallon of fuel	0.444	1.95	0.636	1.96	0.168	0.877
Cost per cetane number, cents per cetane number per gallon of fuel	0.055	0.1147	0.0707	0.1153	0.056	0.073

Notes: No dope is required for the following straight run fuels:
Pennsylvania.....Cetane No. 61
Mid-Continent.....Cetane No. 50
East Texas.....Cetane No. 58
Cost of commercial amyl nitrate taken as $1.00 per gallon, as estimated for quantity production.

approximately $0.02 per gallon to raise the average cracked stock to 50-cetane number. It would cost $0.006 per gallon to raise the average California straight-run fuel to 50-cetane number.

All data accumulated thus far show that ignition accelerators have a very minor effect on economy or power output of the diesel engine; that is to say, if we compare a fuel of 50-cetane number clear to a fuel which has been brought to 50-cetane number by the introduction of a minor amount of ignition accelerator, the economy obtained and the power of the engine will be approximately the same. The diminished economy and power output of the fuel to which the ignition accelerator has been added is proportionate to the reduction in the heat content of the fuel. The reduction in the heat content of the fuel due to commercial amyl nitrate ignition accelerator is illustrated in Table 11, which also shows the low heat content of the commercial amyl nitrate, namely, 11,270 Btu per pound. Data[7] obtained from the Fairbanks-Morse six-cylinder, Model 36A, 4¼-inch-bore by 6-inch stroke diesel engine indicate that as the cetane number of the fuel is increased, whether by the addition of dope or by using a fuel whose inherent cetane number is high, the engine roughness and the rate of pressure rise are both reduced. Other observers[8, 9, 10] have found that engine roughness is reduced when the cetane number of the fuel is raised by the addition of ignition accelerators. The effect on the economy of the above mentioned engine[7] when increasing quantities of commerical amyl nitrate are added to the fuels shown in Table 11, is given in the following data:

FUEL	Cetane No.	Brake Therm. Eff., Percent	Fuel Rate, Lb./Bhp./Hr.
Mid-Continent Cracked	36.3	29.4	0.455
1 Percent Commercial Amyl Nitrate	46.0	29.2	0.460
2 Percent Commercial Amyl Nitrate	52.0	29.0	0.464
3 Percent Commercial Amyl Nitrate	57.0	29.2	0.464
Mid-Continent Straight Run	55.0	29.4	0.438
1 Percent Commercial Amyl Nitrate	68.9	29.4	0.441
2 Percent Commercial Amyl Nitrate	75.5	29.1	0.445
3 Percent Commercial Amyl Nitrate	80.5	28.9	0.452

This diminution in economy parallels the reduction in heat content, as indicated by the almost constant value of thermal efficiency. Incidentally, the thermal efficiency for this engine remained nearly constant at 29 percent of a series of tests covering a wide range of undoped fuels.

Data from the same source[7] reveal that commercial amyl nitrate has a negligible effect upon the duration of combustion. Other data[5, 9] show that ethyl nitrate tends to increase the primary burning rate but has little effect upon the secondary burning rate; also, that the effect on the primary burning rate decreases rapidly with increasing percentages of ignition accelerator. Neither the completeness of combustion nor its effectiveness is changed by the addition of dope to the fuel.

Data for 30 different distillates are shown in Table 12. These data show a considerable variation in cetane response for some fuels, and serve to emphasize the need for caution in the use of Figure 9 for estimating the amount of isoamyl nitrate required for any specific fuel problem. The part of this table which shows the increase in cetane number for each ½ percent increase in amyl nitrate shows that, in general, the first ½ of 1 percent supplies the greatest effect and that the increment of gain diminishes rapidly as more is added. Consequently, the proportionate gain in cetane number is small for quantities of amyl nitrate greater than 3 percent.

All full-scale data at hand indicate that the use of ignition accelerators does not materially increase engine deposits over those produced by an undoped fuel of equivalent cetane number. Data shown in Table 13 indicate that there may be a slight increase in deposits using amyl nitrate. Even so, the difference of 6.1 g. deposit in 66 hours' running may be due to experimental error in scraping and collecting the deposit.

Starting

In general, ignition accelerators have little effect upon the low-temperature-starting ability of a fuel. For example, a fuel of 40-cetane number doped to 50-cetane number may still have the starting characteristics of a fuel of approximately 40-cetane number. This statement is substantiated by the fact that the critical-compression-ratio (C.C.R.) ratings for doped fuels are usually lower than the Delay ratings. This is a distinct disadvantage for a fuel whose cetane number is made up by the addition of an ignition accelerator. There are certain exceptions to this generalization, namely,

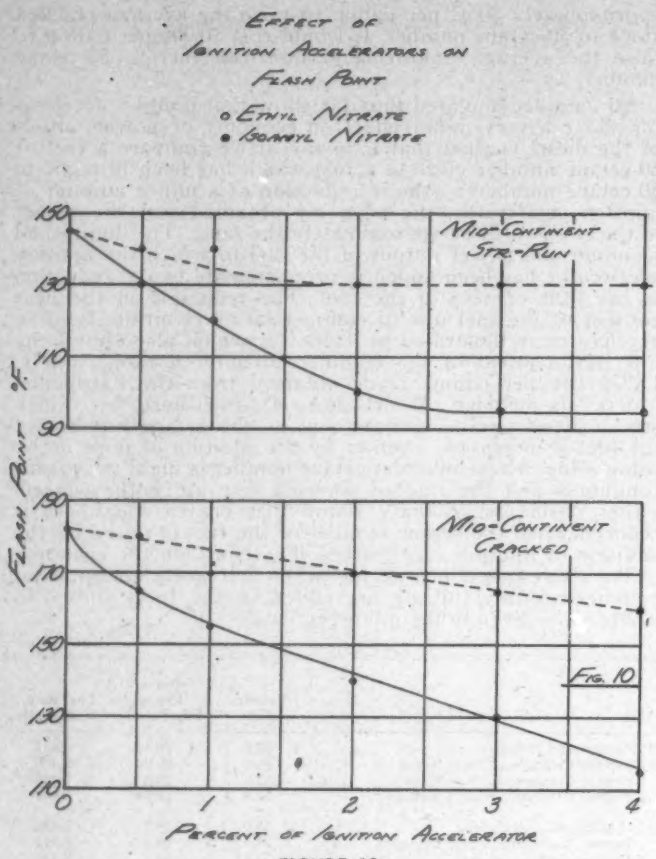

FIGURE 10

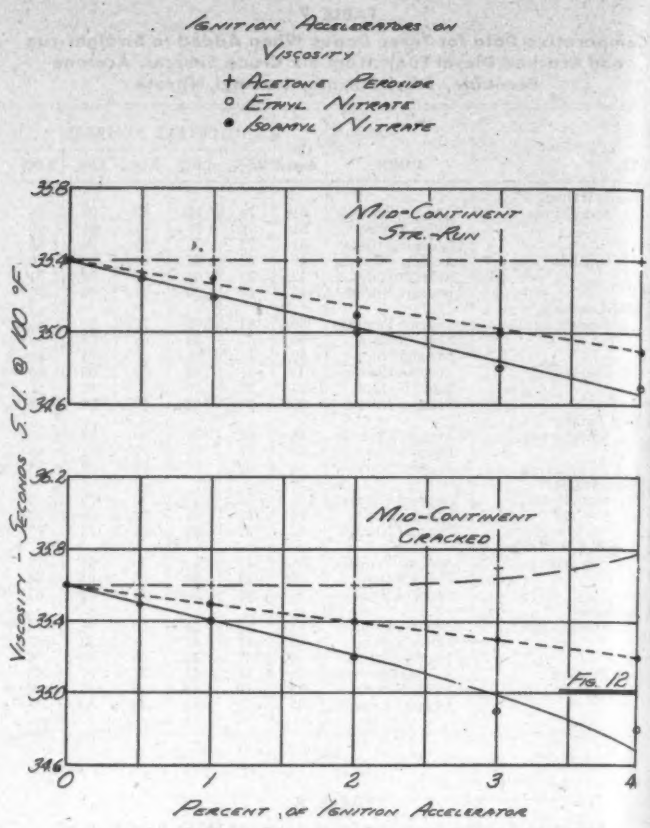

FIGURE 12

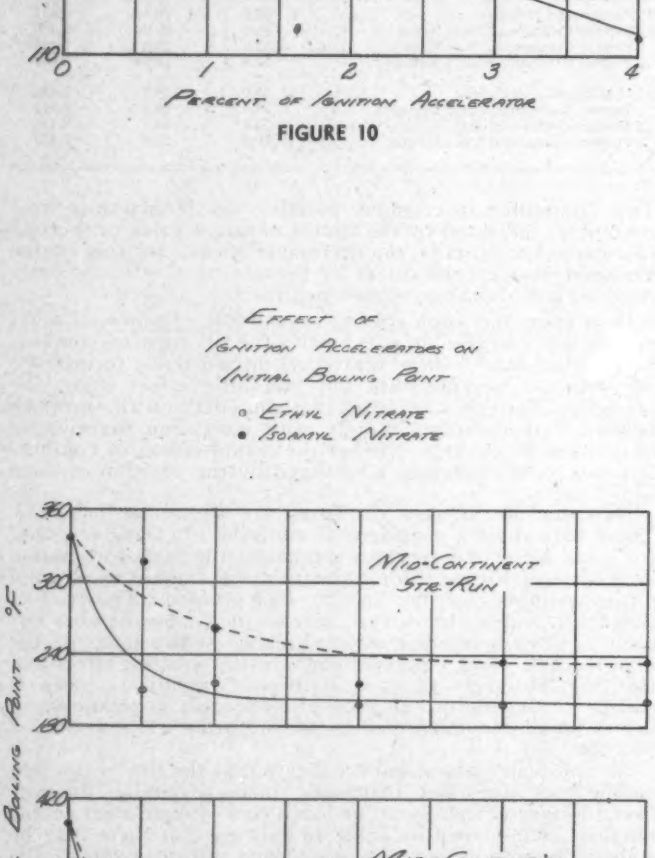

FIGURE 11

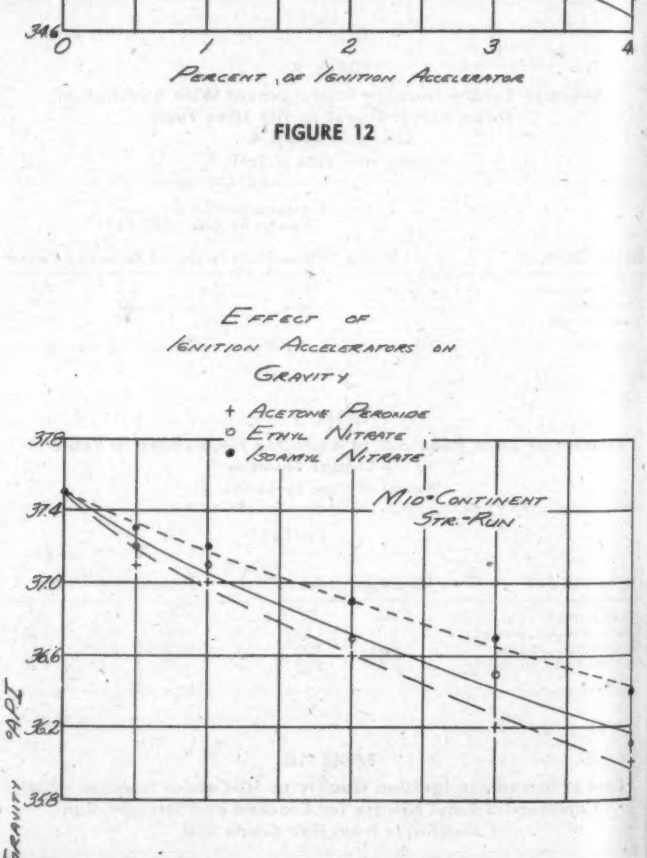

FIGURE 13

TABLE 11

Laboratory Inspection Data Straight-Run and Cracked Mid-Continent Gas Oil to Which Commercial Amyl-Nitrate Has Been Added

FUEL No.	Percent Amyl Nitrate	Viscosity at 100° F. S.S.U.	Gravity at 60° F. A.P.I.	Gravity at 60° F. Specific	Conradson Carbon Percent by Weight	Flash Point (Pm) °F.	DISTILLATION CHARACTERISTICS °F. I.B.P.	10%	20%	30%	50%	90%	E.P.	Cetane No. Delay	Aniline Point °F.	Diesel Index No.	Higher Heating Value B.t.u./Lb.
1*	0	34	28.3	0.8855	0.007	188	374	449	463	476	494	548	610	36.3	102.0	28.9	19,070
1a	1	34	28.1	0.8866	0.094	182	243	449	467	476	494	548	610	46.0	....	....	19,000
1b	2	34	27.8	0.8883	0.210	174	240	448	467	476	494	550	610	52.0	....	....	18,930
1c	3	34	27.7	0.8888	0.290	172	260	439	466	476	494	550	612	57.0	....	....	18,840
2†	0	36	38.1	0.8343	0.010	170	374	434	453	473	512	617	669	55.0	161.2	61.4	19,770
2a	1	36	37.6	0.8368	0.053	168	266	429	453	473	512	617	669	68.9	....	....	19,650
2b	2	36	37.6	0.8368	0.074	164	260	426	452	468	509	617	666	75.5	....	....	19,600
2c	3	35	37.5	0.8373	0.090	158	254	419	453	468	509	617	666	80.5	....	....	19,500
Amyl Nitrate	..	28	11.4	0.9902	....	...	293	298	298	....	....	303	337	....	....	....	11,270

Notes: * Fuel No. 1 is a Cracked Mid-Continent Gas Oil. † Fuel No. 2 is a Straight Run Mid-Continent Gas Oil.
This table was taken from a thesis by Dr. A. F. Robertson—see Bibliography. (No. 7).

the thionitrites, chlorine, and such compounds as exemplified by trichloronitromethane. These compounds all have marked effects toward improving the starting characteristics of the fuel in which they are blended. For maximum starting effect, chlorine may be added to the intake air. This is also true for diethyl ether. However, the starting characteristics of the fuel itself may be improved materially by the addition of the ethers, e.g., diethyl ether, although these compounds apparently do not act as ignition accelerators since their effect is apparently due to the extreme volatility and high critical-compression-ratio rating of the material. This is shown by the fact that as the number of carbon atoms in the alkyl chain is increased and the volatility drops, the effect of the additive as a starting agent is diminished.

Corrosion

If extensive use of the nitrates or peroxides as ignition accelerators for diesel fuels is to be made, a study of their corrosive properties under engine-operating conditions should be undertaken. Data procured in the authors' laboratory show that the peroxides are most corrosive and that the nitrates have a small effect. These compounds cause pitting of the injector nozzle tips, valves and seats. Data obtained from the 6-cylinder, 4-cycle, Fairbanks-Morse engine at the University of Wisconsin[7] indicate that corrosive effect of commercial amyl nitrates is negligible. There has been little extended running of doped fuels on full-scale engines so that no definite conclusions may be drawn as to their corrosive effects.

Conclusions

1. The use of ignition accelerators is a practical means of improving the cetane number and ignition qualities of diesel fuels.

2. Amyl nitrate is the ignition accelerator most likely to be used because, to the authors' knowledge, it is the only one which has had commercial development at this time.

3. The cost of increasing the cetane number with ignition accelerators is dependent upon the susceptibility of the individual stock and the increase necessary, as well as on the ignition accelerator chosen. The average cost probably will be approximately $0.0010 per cetane number per gallon.

4. Ignition accelerators tend to reduce the flash point of usual diesel fuels below the legal limits.

5. Ignition accelerators tend to increase the Conradson carbon on the 10-percent-distillation bottoms but do not materially increase the carbon-deposit formation in the engine.

6. Because of reduced net heat content, fuels to which large quantities of ignition accelerators have been added tend to show a poorer economy than those which by virtue of their natural properties have an equivalent cetane number.

7. Engine roughness is materially reduced by increasing the cetane number with ignition accelerators; however, the completeness of combustion is not affected.

8. With a few exceptions the majority of the ignition accelerators known to the authors have little effect upon the low-temperature-starting quality of a diesel fuel regardless of the quantity added.

9. Some ignition accelerators may have serious corrosive effects. Before any extensive use is made of these materials, a complete study of the corrosion tendencies should be made because there are too little data to allow prognostication at this time.

10. To date it is doubtful whether or not ignition accelerators can be economically justified. West Coast fuels need to have their cetane number increased by some method and it would seem most practical to use a combination of solvent extraction and small quantities of ignition accelerators. The solvent refining process will increase markedly the ignition

TABLE 12

Cetane Response for Addition of Amyl Nitrates to Distillate Fuels from United States Crude Sources

	Amyl Nitrate, in %		CETANE NUMBER					INCREASE IN CETANE NUMBER (From Curve)						
	Str. Run	Cracked	0	0.5	1.0	2.0	3.0	0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0	2.0 to 2.5	2.5 to 3.0	Ref.*
1. Reference Fuel	..	..	74	82	90	100+	..	8.0	8.0	8.0	8.0	....	....	a
2. Pennsylvania	X	..	61	72	76	83	90	11.0	4.0	3.5	3.5	3.5	3.5	7
3. East Texas	X	..	58	67	71	78	82	8.5	5.0	3.5	3.0	2.2	1.8	7
4. Michigan	X	..	57	70	76	81	..	13.2	6.0	2.8	2.2	2.0	....	b
5. Diesel Fuel	..	..	56	62	68	72	..	6.5	5.5	3.0	1.0	0.7	....	a
6. Mid-Continent	X	..	55	63	69	76	81	8.3	5.7	4.0	3.0	2.5	2.5	11
7. Mid-Continent	X	..	54	67	69	..	..	14.0	2.0	2.0	....	....	....	a
8. Mid-Continent	X	..	54	65	70	73	..	11.0	5.0	2.0	1.0	....	....	b
9. Mid-Continent	X	..	53	..	66	..	..	7.0	6.0	....	....	....	....	b
10. Mid-Continent	X	..	50	57	63	69	74	7.0	5.5	3.8	3.0	2.5	2.2	5 & 7
11. Wyoming	X	..	50	..	65	..	..	8.8	6.2	....	....	....	....	b
12. Kerosene	..	..	49	54	56	60	61	4.4	3.4	2.0	1.2	0.7	0.3	a
13. Diesel Fuel	..	..	48	53	56	59	61	5.0	3.0	1.7	1.3	1.1	0.9	a
14. Furnace Oil	..	..	48	56	62	71	79	8.0	6.0	4.6	4.4	4.0	4.0	a
15. West Texas	X	..	47	52	58	64	73	5.6	4.7	4.3	3.9	3.8	3.7	7
16. California	X	..	44	52	54	60	..	5.5	4.5	3.7	2.3	....	....	a
17. Mid-Continent Blend	50%	50%	43	51	56	..	..	8.0	5.0	....	....	....	....	b
18. Pennsylvania	..	X	42	50	56	64	66	8.0	6.0	4.6	3.4	1.3	0.7	7
19. California	X	..	41	47	52	59	63	6.0	5.0	4.0	3.0	2.3	1.7	7
20. California	X	..	40	49	53	56	..	9.0	4.0	1.8	1.2	0.8	....	a
21. East & West Texas	..	X	38	44	50	57	62	6.0	5.5	4.3	3.2	2.6	2.4	7
22. Gas Oil	..	X	38	45	48	60	..	6.5	5.7	5.3	4.5	....	....	a
23. Mid-Continent	..	X	36	42	46	52	57	7.0	4.2	3.1	2.8	2.6	2.3	11
24. Pennsylvania	..	X	35	45	51	58	..	10.5	5.0	4.0	3.5	....	....	12-IX
25. East Texas	..	X	34	42	46	49	..	6.0	5.0	2.5	1.5	1.3	....	a
26. Mid-Continent	..	X	33	38	42	49	54	4.7	4.3	4.0	3.0	2.7	2.3	6 & 7
27. California	..	X	33	39	44	49	54	6.0	5.0	3.0	2.5	2.1	1.9	7
28. Mid-Continent	..	X	32	40	42	49	..	6.8	4.7	3.0	2.5	1.9	....	12-IX
29. Mid-Continent	..	X	28	..	45	..	..	10.0	7.0	....	....	....	....	a
30. Illinois	..	X	26	32	36	41	46	6.0	3.8	3.1	2.6	2.5	2.0	12-IX

*References: Numbers in reference column refer to tables in this paper for which isoamyl nitrate was used. All other data are for commercial amyl nitrate.
12-IX refers to Table 9 in Bibliography Reference No. 12.
a Data furnished by Sharples Chemicals, Inc., Philidelphia, Pennsylvania, (12-6-38).
b Data furnished by Sinclair Refining Company, East Chicago, Indiana. (3-23-39).

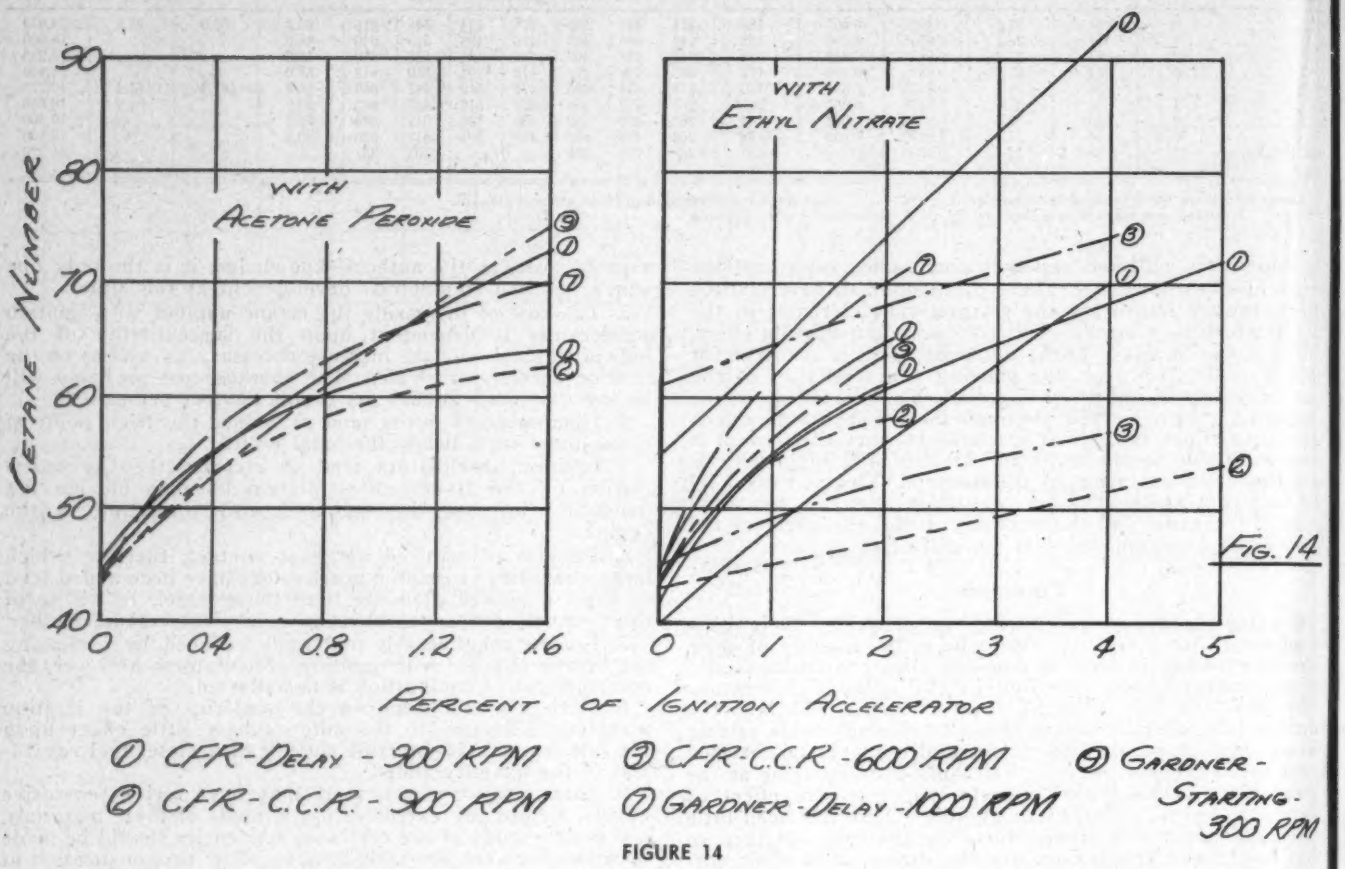

FIGURE 14

TABLE 13

Engine Deposits Using Mid-Continent Recycle Stock With and Without Commercial Amyl Nitrate

RUN NO. 1—Mid-Continent Recycle Stock. Weight of Combustion Deposits in Grams:

	Cylinder No. 1	Cylinder No. 2	Cylinder No. 3
Intake Valve and Port	0.1	0.1	0.1
Exhaust Valve and Port	5.9	1.9	0.4
Head	3.0	0.7	1.1
Piston Crown and Liner	3.3	2.1	2.0
Total	12.3	4.8	3.6
Total all Cylinders	20.7		

RUN NO. 2—Mid-Continent Recycle Stock plus 1 percent commercial nitrate. Weight of Combustion Deposits in Grams:

	Cylinder No. 1	Cylinder No. 2	Cylinder No. 3
Intake Valve and Port	0.3	0.1	0.2
Exhaust Valve and Port	8.4	0.5	0.1
Head	3.9	1.7	1.8
Piston Crown and Liner	5.8	2.0	2.0
Total each Cylinder	18.4	4.3	4.1
Total all Cylinders	26.8		

In the above tests, the three cylinder, 5¾" bore Caterpillar Diesel engine was run at no load, high idle speed, and at a simulated altitude of 5,000 feet. The duration of each test was sixty-six hours. Although no data was obtained on Runs No. 1 and No. 2, a subsequent run using Diesel fuel gave the following pertinent data:

Manifold Temperatures, °F.

	Cylinder No. 1	Cylinder No. 2	Cylinder No. 3
Water	135°	145°	165°
Exhaust	285°	320°	350°

Note: The data for this table was furnished by the Caterpillar Tractor Company, Peoria, Illinois.

accelerator susceptibility of the fuel.

11. It will be approximately one year from the time a commercial demand arises before amyl nitrate can be made available in commercial quantities.

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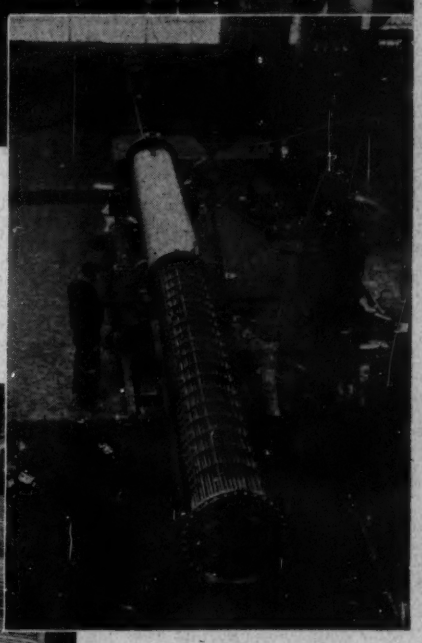

(below)
Tube bundles being assembled in the shop of a large refinery.

(above)
Hand winch draws tube bundle into heat-exchanger shell. Note simple method of supporting bundle.

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LITERATURE AND PATENT SEARCH

Ignition Accelerators for Compression-Ignition Engine Fuels

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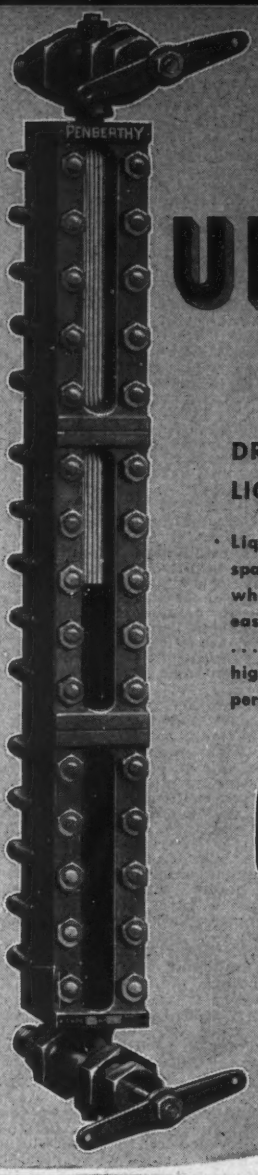
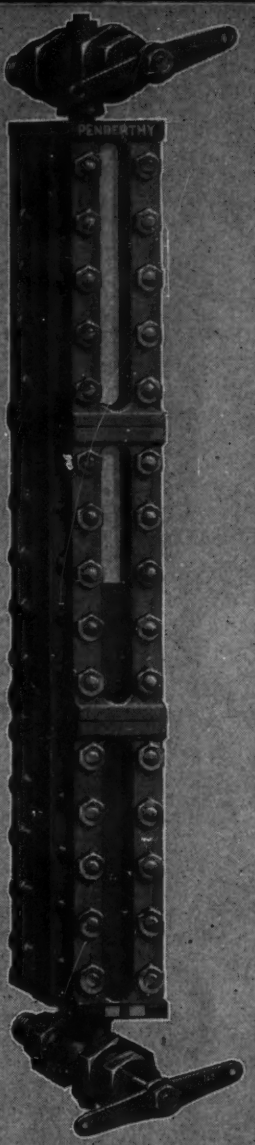
42. Alcohols and ethers (See C 20).
43. de La Riboisiere, Jean Felix Paul, U. S. Patent 1,519,905 (December 16, 1924). A monohydroxy phenol is used to retain ether in small proportions in liquid hydrocarbon fuels.
44. Rosen, R. (Standard Oil Development Company), U. S. Patent 2,261,290 (November 4, 1941). To enhance its ignition quality a hydrocarbon fuel is blended with an ester of phosphoric acid and especially those containing thioand alkyl group substituents, e.g., tri-alkaryl tetrathiophosphate and triparacresyl tetrathiophosphate.
45. Nitroglycerine (See D 67).
46. Ruigeraw-Kahl., German Patent 221,469 (October 18, 1906). Motor fuel has added 1 percent of ether or carbon disulfide. (J 17).
47. Rutzbeck, A. V., British Patent 375,525 (June 30, 1932). Ethyl alcohol as ignition accelerator.
48. Solomon, E., British Patent 461,321 (February 12, 1937). A fuel oil for heavy-oil engines; prepared by mixing one or more of the following: methyl alcohol, dichlorethylene, acetone, powdered coal, or coke, coal oil, lime, soda, water, ammonium chloride, etc. The oil obtained is mixed with petrol, etc. (K 70).
49. Standard Oil Development Company, German Patent 673,139 (1939). Diesel fuel consisting of gas-oil or kerosine, containing a small proportion of high-molecular organic oil-soluble acids or esters, and if desired, small quantities of compounds containing halogen or sulfur and/or metal compounds, particularly lead compounds, also generation of additional substances in the fuel itself by oxidation or chlorination. (C 26, H 24, K 81).
50. Esters as described in British Patent 402,262 (November 30, 1933) on amyl stearate, butyl acetyl ricionoleate, benzyl or hexyl esters of wax-oxidation acids. (See K 79).
51. Steele, C. C. D. and Clifton, H. B. British Patent 174,712 (February 9, 1922). Camphor, naphthalene, benzene methyl alcohol, ammonia, turpentine, ether, and sulfur as ignition accelerators. (K 83).
52. Tennant, W. J. (from A. H. Fleming). British Patent 461,671 (February 17, 1937). B.C.A.-B, 412 (May, 1937). A diesel engine fuel is prepared by mixing furfuraldehyde (5-95 percent) with a liquid fuel boiling at >150°. Such a mixture may also be diluted with >49 percent of low-boiling fuels, e.g., benzene, ethyl alcohol. Swiss Patent 187,-127.
53. Terakopoff, R. G., British Patent 448,-446 (June 8, 1936) B.C.A.-B 778 (1936). Addition of 1 percent of a mixture of paraldehyde (20-50 parts by vol.) and a polycyclic hydrocarbon (50-80), e.g., tetrahydronaphthalene, to liquid fuels assists in promoting fuel combustion. An aromatic amine, e.g., NH_2Ph, NHPhMe, or preferably aminocymene, may be present. (K 85).
54. Terakopoff, R. G., British Patent 449,-160 (June 22, 1936). Motor fuel is im-

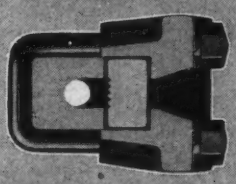
QUALITY UNCOMPROMISED





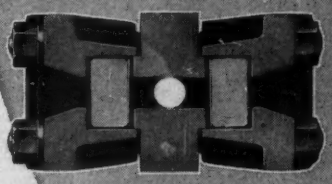
PENBERTHY
Reflex
DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.



PENBERTHY
Transparent
DROP FORGED STEEL LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . similar to Reflex types.

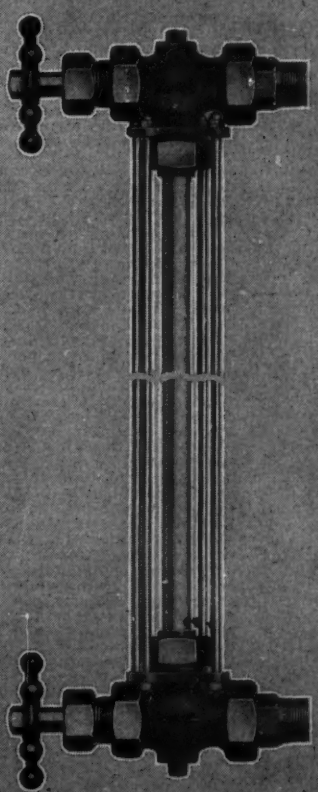


Penberthy Liquid Level Gages

ALL PENBERTHY GAGES
CONFORM WITH A. P. I.—A. S. M. E. REQUIREMENTS

PENBERTHY
Reflex
WATER GAGE SET

Water shows black—steam shows white. U-bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler.



PENBERTHY
DROP FORGED STEEL LIQUID LEVEL GAGES

Made of Chromium-molybdenum alloy temperature-resisting steel, extra heavy throughout. Stainless steel trimmed. Tubular glass type gages also available in various other metals suitable for practically all conditions.

PENBERTHY INJECTOR CO.

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PENBERTHY PRODUCTS

proved by adding a mixture of ether, paraldehyde, tetrahydronaphthalene, and an upper-cylinder lubricant. Mixture may contain acetone, a solid lubricant, graphite, and aniline, toluidine, etc. Lubricants specified are fish, animal, vegetable, and mineral oils. (K 86).

55. Aldehydes and ketones (See I 49).
56. Tunison, R. B., U. S. Patent 1,423,049 (July 18, 1922). Petroleum distillates heavier than kerosine mixed with ethyl acetate in the proportion of 2:1.
57. Alcohol (See E 38, E 39).
58. U. S. Industrial Alcohol Company, U. S. Patent 1,423,048 (July 18, 1922). Alcohol, ether, esters, ketones and combinations thereof for improving diesel fuels.
59. Weber, E. M., French Patent 812,649 (May 13, 1937). Aldehydes, ketones, and nitro compounds as ignition accelerators. (D 82).
60. Weber, M. E., Belgian Patent 405,812 (October 22, 1934). Fuel for diesel engines. Motor fuels have added explosives, and nitrites; aldehyde may be added. (D 83, E 40).
61. Woodbury, C. A. and Lawson, W. E. (Du Pont Company). U. S. Patent 2,066,506 (January 5, 1937). The delay period between injection and ignition of fuel oil is reduced and either the ignition temperature of the fuel oil and/or the compression ration is lowered by addition of a small quantity, e.g., 5 percent, of a nitrate of an aliphatic polyhydric alcohol containing groups which increase their solubility in fuel oil; e.g., B-propylene glycol dinitrate, Et-ether of glycerol dinitrate, and glyceryl monochloride dinitrate. (D 91).

C. Metal Derivatives

1. Belknap, C. B., U. S. Patent 1,533,158 (April 14, 1925) Emulsified liquid hydrocarbon fuel. A mixture of hydrocarbon oil, copper oleate, and ammonium nitrate.
2. Vanadium pentoxide (See H 2).
3. Barium nitrate, aluminum (See K 17).
4. Egerton, A. C., J. Inst. Petroleum Tech. 13, 244-72 (1927). British Patent 281,-299 (May 10, 1928). The effect of metallic vapors on ignition of substances. Lead raises the self-ignition temperature.
5. Bismuth nitrate derivative of ethyl cinnamate (See D 25).
6. Lead salt of higher aliphatic or resin acids, or lead linoleate or borate (See B 22).
7. Hale, G. C. and Rinkenbach, W. H., U. S. Patent, 2,116,514 (May 10, 1938). A priming composition consisting of normal lead dinitroresorcinate.
8. Howes, D. A. (Imp. Chem. Ind.), U. S. Patent 2,054,628 (September 15, 1936). C. A. 30, 7838 (1936). A high-boiling oil is used with an admixture of about 0.5-5.0 percent each of ethyl nitrate and an oxygenated organic compound of copper such as copper oleate, copper acetyl acetone, or copper propionyl acetone which serves as a primer. (D 38).
9. Copper oleate or stearate (See D 41).
10. Oxygenated copper compounds such as copper oleate or stearate (See D 45).
11. Leum, L. N., U. S. Patent 2,266,776 (December 23, 1941). J. Inst. Petroleum 28, 374 (1942). Preparation of a compression-ignition fuel consisting of a fuel having an IBP of at least 300° F. and an organic borine-amine addition compound in sufficient quantity substantially to increase the cetane number of the fuel; the structure of the borine compound is such that the boron atom is directly attached to a carbon atom only singly bonded to other atoms.
12. Leum, L. N., U. S. Patent 2,267,701 (December 23, 1941). J. Inst. Petroleum 28, 374 (1942). Similar to C12, addition compound being an organic borine.
13. Mac Lean, G. and Sisson, E. G., Jr., U. S. Patent 1,916,735 (July 4, 1933). The use of manganese soap as an ignition accelerator for diesel fuels.
14. Miller, P. and Cloud, G. H., (Standard Oil Development Company), U. S. Patent 2,258,297 (October 7, 1941). The ignition lag of an injected hydrocarbon diesel engine fuel is shortened by the admixture of about 0.5-5 percent of an alkyl mercury or antimony compound or the like.
15. Mohrle, A., U. S. Patent 1,877,936 (September 20, 1932). Starting cartridge suitable for starting crude-oil engines. Use of potassium nitrate and phosphorus sesquisulfide. (J. 13).
16. Potassium chlorate (See K 52).
17. N. V. de Bat. Pet. Maat., British Patent 395,192 (August 13, 1933). Anti-knock value of diesel oil, etc., raised by adding metal compounds of condensation products of primary amines with oxyaldehydes, ketones, etc., trikestones. Also French Patent 742,957. (B 37).
18. Manganese dioxide (See I 36).
19. de La Riboisiere, J. F. P., British Patent 244,797 (March 17, 1927); U. S. Patent 1,558,967 (October 27, 1925). Increasing the efficiency of fuels for diesel engines or internal-combustion engines. Use of 0.1 to 0.2 percent of dibenzyl diselenide, diphenyl sulfide or benzylsulfide. (J 16).
20. de La Riboisiere, J. F. P., U. S. Patent 1,534,573 (April 21, 1925). Fuel for internal-combustion engines. A hydrocarbon oil fuel containing considerable proportions of hydrocarbons boiling above 160° C. and which may contain alcohol and ether, is mixed with phenyl compounds such as those of selenium, tellurium, thallium, uranium, tungsten, titanium, bismuth, vanadium, and aluminum, dibenzylsalicylate, benzylamines, benzylalilines, benzyl alcohols, benzylhydroxyamines, etc., to increase the power developed and to decrease the consumption of the fuel. British Patent 243,357 (1924). (B 42, K 59).
21. Roberts, A., British Patent 438,351 (March 10, 1934). Relates to the direct addition of oil-soluble boron compounds such as ethyl and methyl borate to fuel oil and to the emulsification of water-soluble boron compounds such as boric acid with the fuel oils to aid and/or control combustion in internal-combustion engines.
22. Roberts, A. A. (Imperial House, Kingsway, London), British Patent 434,109 (August 27, 1935). Liquid fuel for diesel engines is obtained by emulsifying a minor proportion of water in oil fuel by means of casein or a carbyhydrate colloid such as starch. Agents controlling combustion, e.g., boron compounds and/or sodium chloride, and naphthalene to reduce the viscosity may be added. In an example, a solution of ⅜-pound of borax and ⅜-pound of sodium chloride in 4 pounds of water is emulsified in 100 pounds of petroleum oil by ½-pound of starch. Emulsification is preferably effected by passage through 1 or more high-speed attrition mills. Specifications 408,951, 433,348, and 434,180 are referred to.
23. Rosen, R. (Standard Oil Development Company), Canadian Patent 359,289 (July 21, 1936) Hydrocarbon composition. A hydrocarbon oil boiling above the kerosine range and containing an oil-soluble metallo-organic agent. Metals of the 2nd, 3rd, and 5th groups, phosphorus, and sulfur are used.
24. Standard Oil Development Company, British Patent 523,522 (August 16, 1940). Diesel dopes containing mercury, barium, tin, zinc, or calcium. The efficiency of these compounds does not seem great.
25. Lead or tin compounds (See K 79).
26. Metal compounds, particularly lead (See B 49).
27. Standard Oil Development Company, French Patent 853,717 (March 27, 1940). C.A. 36, 2708[2] (1942). Fuel composed of liquid hydrocarbons, the boiling points of which are in the range of diesel-motor fuels, and of a small proportion of a dissolved organometallic compound comprising a metal belonging to the heavy metals of the groups II and V of the periodic system. Suitable organometallic compounds are mercury alkyl nitrate, barium diphenylamine sulfonate, and tributyl antimony.
28. Stettbacher, A., Nitrocellulose 8, 3-6, 21-7 (1937). C.A. 32, 3963 (1938). Lead trinitroresorcinate.
29. Zerbe, O., Angew. Chem. 46, 659-62, (1933); 45, 593 (1932); Catalytic influences in auto-ignition processes. The catalytic influence of 22 metals and metal compounds discussed.

D. Alkyl Nitrates, Nitrites, and Nitro Compounds

1. Applebey, M. P. (Imp. Chem. Ind.) Canadian Patent 347,545 (January 15, 1935). Similar to C 8.
2. Aubert, M., Compt. Rend. 201, 879-81 (1935). The influence of various additions to the fuels of injection motors. Marked effect of ethyl nitrate in suppressing knock and diminishing ignition delay is demonstrated with additions of 5 percent and more.
3. Bassett, H. N., Chem. & Ind. 570-3 (1937). C.A. 31, 5975 (1937). Ethyl nitrate decreases knocking.
4. Bereslavsky, E. V., U. S. Patent 2,158,050 (May 16, 1939). Motor fuel. A liquid fuel for compression-ignition engines; a high-boiling petroleum hydrocarbon distillate, of gas-oil type, and 10 percent of a pentyl nitrate of group n-butylcarbinol nitrate, sec. butyl, methylpropylcarbinol nitrate, and diethylcarbinol nitrate.
5. Bereslavsky, E. V., French Patent 821,-211 (November 30, 1937). Improved fuel for internal-combustion motors, particularly compression-ignition motors, consisting of a hydrocarbon distillate from petroleum of high boiling point having a total sulfur content of less than 0.25 percent by weight and containing in solution less than 10 percent by volume of an ignition accelerator chosen from the group comprising the nitrates, of the mono-alkyls, poly-alkyls, amyl nitrates, the peroxides of ketones, and the peroxides of anhydrides from fatty acids. (I 3).
6. Bereslavsky, E. V., Canadian Patent 384,497 (October 10, 1939). A pentyl nitrate or mixtures thereof as a diesel ignition accelerator.
7. Bereslavsky, E. V., British Patent 479,-969 (February 15, 1938) B.C.A.-B, 482 (1938). Fuels are improved and their cetene or cetane numbers raised by the addition of >10 vol. percent of one or more amyl nitrates.
8. Bereslavsky, E. V., Canadian Patent 375,853 (August 16, 1938). A liquid motor fuel for internal combustion engines.
9. Ethyl nitrate (See I 5).
10. Trichloronitromethane (See K 7).
11. Callender, H. L., Engineering, 11-16 (February 4, 1927). Reduction in H.U.C.R. with addition of amyl nitrate to a spark ignition engine fuel.
12. Clarke, L. A., U. S. Patent 2,274,665 (March 3, 1942). J. Inst. Petroleum 28, 284A (1942). A liquid diesel fuel containing a small quantity of trichloronitromethane which serves as a primer. (K 10).
13. Clarke, L. A. and Pevere, E. F., U. S. Patent 2,274,666 (March 3, 1942). J. Inst. Petroleum 28, 284A (1942). The use of about ¼ percent of dichlorodinitromethane, dichlorotetranitroethane, or tetrachlorodinitroethane decreases the ignition delay period of the fuel, improves its cold starting ability, and decreases its tendency to deposit carbon and carbonaceous materials in the motor combustion chamber. (K 10).
14. Cloud, G. H. (Standard Oil Development Company), U. S. Patent 2,280,217 (April 21, 1942), C.A. 36, 5337[1] (1942). A fuel suitable for high-speed diesel engines is formed of a hydrocarbon fuel with a flash point above 150° F., together with a small proportion of decyl, dodecyl or cetyl nitrate or other alkyl nitrate having at least 10 carbon atoms which serves to accelerate ignition.
15. Cloud, G. H. (Standard Oil Development Company), U. S. Patent 2,304,242 (December 8, 1942). Diesel fuel containing as ignition improver and stabilizing agent phenylhydrazine or derivatives thereof, with small amounts of aliphatic nitrates, nitrites, polysulfides, or aromatic peroxides. (I 7, J 3, K 13).
16. Copertini, S., Italian Patent 341,075 (April 4, 1936). Adds to a motor fuel a nitro-compound, nitroglycerine, nitronaphthalene, etc. (E 6).
17. de Crater, W. (Hercules Powder Company), U. S. Patent 2,112,749 (March 29, 1938). C. A. 32, 3964 (1938). Nitroisobutylglycerol trinitrate and nitroisobutylglycol dinitrate as diesel dopes.
18. Duchene, R., Pub. Sci. Tech. Ministere Air (France), No. 94, 17 pp. (1936). "The addition of alcohols or benzaldehydes to the gasoil increases the pressure developed but increases the ignition delay. Ethyl nitrate decreases the delay from three milliseconds to less than one millisecond with an increase in pressure." (B 16.)
19. Esters of nitric or nitrous acid (See I 11).
20. Ellis, Carleton (Standard Oil Development Company); U. S. Patent 2,274,629 (February 24, 1942). A hydrocarbon diesel fuel oil is mixed with a smal proportion of a compound such as a nitrodihydroxy alcohol in which at least one of the C atoms joined to a nitrate group is a secondary C atom joined to an alkyl group, to improve the ignition qualities of the fuel.
21. Foord, F. A., J. Inst. Petr. Tech. 18, 533-47 (1932). The ignition properties of fuels could be improved considerably by the addition of ethyl nitrate.
22. George, R. S. (Socony-Vacuum Oil Company), U. S. Patent 2,307,624 (January 5, 1943) C. A. 37, 3588[3] (1943). Production of organic thionitrates, as for use in improving the ignition quality of diesel fuels. (K 22).
23. Good, R. F., S.A.E. Journal 40, 232-42, 251T (1937). Engine operation data are given for cetane, alphamethylnaphthalene mixtures, and for diesel fuels, some containing ethyl nitrate and lead tetraethyl.
24. Nitro compounds, general (See H 5).
25. Griffith, R. H. and Hill, S. G. (Gas Light & Coke Company) British Patent 436,027 (October 3, 1935). Fuel oils are primed with a small percentage of an organic compound which has a halogen atom and a nitro group on adjacent carbon atoms, and has an ignition point appreciably lower than the oil. The primer may be formed from a hydrocarbon, an acid, an oxy- or hydroxy-body, or salt. Addition to creosote oil and gasoil and gasoil mixture of 0.5-1 percent of 9,10-brom-stearic acid nitrate or ester, bromopinene nitrate, chlorostearic acid nitrate, or bismuth nitrate derivative of ethyl cinnamate. (B 20, C 5, K 20).
26. Amyl nitrate (See K 23).
27. Heinze, R., Marder, M., and Veidt, M.,

TUBE-TURN WELDING FITTINGS—RANGE OF SIZES

Type of Fitting	Description	Standard Weight	Extra Strong	Schedule 160	Double Extra Strong	Light Gauge Nominal Pipe Size	Light Gauge Iron Pipe Size
Elbows	90° Long Radius	½"-24"	¾"-24"	1"-12"	1"- 3"	4"-24"	3"-12"
Elbows	90° Short Radius	1"-30"	1½"-30"				
Elbows	45° Long Radius	½"-30"	¾"-30"*	1"-12"	1"- 8"	4"-24"	3"-12"
Returns	180° Long Radius	½"-24"	1"-24"	1"-12"	3"- 8"	4"-24"	
Returns	180° Short Radius	1"-30"	1½"-30"				
Returns	180° Extra Long Radius	1"-2½"	1"-2½"				
Tees	Straight	¾"-24"	¾"-24"	1"-12"	1"- 8"		
Tees	Reducing Outlet	¾"-24"	¾"-24"	¾"-12"	1"- 8"		
Reducers	Concentric & Eccentric	1x⅜-24x20	1x⅜-24x20		1x⅜-12x10		
Caps		1"24"	1"-24"		1"- 8"		
Stub Ends	Lap Joint	1"24"	1"-24"				
Nipples	Shaped, 90° to Header	1¼"-12"	1¼"-12"				
Nipples	Shaped, 45° to Header	1¼"-12"	1¼"-12"				
Saddles			2"-24" **				
Laterals	Straight	1¼"-24"	1¼"-24"				
Laterals	Reducing-on-Run	1¼"-24"	1¼"-24"				
Crosses	Straight	¾"-24"	¾"-24"				
Rings	Welding	¾"-12"	¾"-12"				
Sleeves	Welding		2"-24" **				

SUPER Tube-Turn 45° long radius elbows, 90° long radius elbows, and 180° long radius returns available in both Standard weight and Extra Strong in sizes from 3" to 12".

Tube-Turn welding fittings and flanges conform to applicable ASA and ASTM Standards. For further details please refer to Tube Turns catalog and data book No. 111.

*30" size short radius.

** Since saddles and sleeves are used for external reinforcement only, they do not conform to iron pipe size thicknesses.

TUBE-TURN FORGED STEEL FLANGES—RANGE OF SIZES

	150 Lb.	300 Lb.	400 Lb.	600 Lb.	900 Lb.	1500 Lb.	2500 Lb.
Welding Neck	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Slip-On	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Lap Joint	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"	½"-24"	½"-24"
Threaded	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Blind	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Socket Type	½"-24"	½"- 4"		¼"-3½"	½"-24"		
Reducing-threaded or slip-on	¼"-24"	¾"-24"	¾"-24"†	¾"-24"	¾"-24"*	¾"-24"	¾"-12"
Orifice—threaded	¾"-24"	1"-24"	4"-12"	4"-12"	3"-12"	1"-12"	
Orifice—slip-on		1"-24"					
Orifice—welding neck		1"-24"	4"-12"	1"-12"	3"-12"	1"-12"	
Long Welding Neck	1"-24"	1"-24"	1"-10"	1"-10"	1"-10"	1"-10"	

†Dimensions on sizes thru 3½" same as for 600 lb. flanges.
*Dimensions on sizes thru 2½" same as for 1500 lb. flanges.

The FIRST SEAMLESS WELDING FITTINGS 1ST AND STILL THE BEST

TUBE-TURN® TRADE MARK

Welding Fittings and Flanges

TUBE TURNS (Inc.) LOUISVILLE, 1, Ky. *Branch offices:* New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Houston, Seattle & San Francisco. *Distributors in principal cities.*

Chem. Fabrik, 14, (1941). Aside from the alkyl nitrates and nitrites there are a number of active accelerators for improving diesel fuels including tetralin peroxide, ethylenochlorohydrin nitrate, nitrosomethylurethane, and diethyltetrasulfide. Storage tests (6 months) with accelerators in more or less common use showed no significant loss in potency. (G 2, I 13, J 8, K 24).

28. Heinze, R., Marder, M., and Veidt, M., Oel U. Kohle 37, 422-30 (1941). C. A. 36, 4993[7] (1942). Same as D 27.

29. Heinze, R., Marder, M., and Veidt, M., Chem.-Ztg. 65, No. 31/32, 149 (1941). Cetane number of diesel fuels is increased by the addition of a small amount of materials such as alkyl nitrates, nitrites, or peroxides, halogen nitrates, nitroso-compounds, and polysulfides. (I 14, J 9, K 25).

30. Helmore, W. (Imp. Chem. Ind.), British Patent 352,350 (July 9, 1931). The use of ethyl nitrate to improve ignition quality of diesel fuels.

31. Helmore, W. (Imp. Chem. Ind.), British Patent 354,398 (August 13, 1931); U. S. Patent 1,. 849,051 (March 8, 1932). Motor fuel for diesel engines. To the high-boiling mineral oil, are added two or more primers, one of which is an ignition primer (methyl or ethyl nitrate) and the other an exploding primer (benzoylperoxide, amylene peroxide, picric acid, dinitrobenzene, trinitroglycerine, or trinitrotoluene). French Patent 564,899 (1931). 730,238 (1932). (B 24, E 12, I 15).

32. Helmore, W. (Imp. Chem. Ind.), British Patent 352,550 (July 13, 1931). Similar to D 31.

33. Helmore, W. (Imp. Chem. Ind.), British Patent 366,947 (February 3, 1932). Addition to D 31.

34. Helmore, W., German Patent 564,899 (November 24, 1932). Process for making a fuel for compression-ignition engines in which substances that will lower the ignition temperature of the heavy hydrocarbon oil or improve its combustion are added, such as alkyl nitrates, which contain oxygen. At least two kinds of oxygen are supplied to heavy fuels like shale oil, one in a substance with a lower self-ignition temperature than that of the oil, to initiate ignition, and the other, to ignite the fuel, in a substance whose self-ignition temperature is higher than of the first additive and if necessary higher than that of the fuel itself. The first additive may be methyl or ethyl nitrate and the second may be a peroxide of an organic substance or an organic polynitro compound. At least one of the primers is first dissolved in another primer. (E 13, I 16).

35. Nitro compounds (See H 8).

36. Holmann, F., and Gieseler, K., German Patent 574,678 (April 19, 1933). Addition of a small percentage of nitro products of aliphatic or hydroaromatic hydrocarbons, nitrohexane, nitromethane, and nitrated mineral oil hydrocarbons. (A 5, E 15).

37. Howes, D. A., Proc. World Petrl. Congress Sect 2, 781 (1933). Substitute diesel fuels. Suggests combustion accelerators to enable the use of aromatic and naphthenic oils from coal hydrogenation and ethylene polymers. Alkyl nitrates and nitrites reduce ignition delay but are required in high proportions to effect noticeable improvement and are expensive.

38. Ethyl nitrate (See C 8).

39. Howes, D. A. (Imp. Chem. Ind.), U. S. Patent 2,065,588 (December 29, 1936). C. A. 31, 1192 (1937). The use of two primers is recommended for high-boiling fuel for diesel engines, the first being 0.5 to 5.0 percent of an alkyl nitrate (ethyl nitrate) or nitrite (amyl nitrite) and the second, an equal quantity of benzyl bromide. (K 26).

40. Howes, D. A. (Imp. Chem. Ind.). Canadian Patent 347,544 (January 15, 1935). Similar to C 8.

41. Howes, D. A. (Imp. Chem. Ind.). British Patent 404,682 (January 22, 1934). To increase ignition the oils have added 2 percent of an alkyl nitrate of 2-4 carbon atoms (ethyl nitrate) and an organic bromide compound (benzyl bromide, cyclohexylbromide, butyl bromide) with or without copper oleate, stearate, or propionylacetonate. (B 28, C 9, K 28).

42. Imp. Chem. Ind, New Zealand Patent 71,126 (1934). Similar to D 41.

43. Imp. Chem. Ind., French Patent 757,326 December 23, 1933). Similar to D 41.

44. Imp. Chem. Ind., Norwegion Patent 52,872 (1932-1933). Preparation of a fuel for diesel-type motors. Addition of small amounts of alkyl nitrate to heavy fuel oil. The alkyl nitrate contains 2-4 carbon atoms. The heavy oil is either creosote oil or an oil obtained by the hydrogenation of coal. The nitrate is previously dissolved in a solvent such as turpentine oil, petroleum, alcohol, acetone, or ether. (B 29).

45. Imp. Chem. Ind., French Patent 760,759 (1933); Swiss Patent 168,450 (1934). An alkyl nitrate or nitrite, to shorten the delay period, and an organic bromine compound to reduce the temperature of self-ignition are added to fuel for a compression-ignition engine. The bromine compound may be benzyl or butyl bromine. An oxygenated copper compound such as copper oleate or stearate may be used. The quantity of material to reduce the delay period does not exceed 2 percent, and 0.1 percent of the material to reduce the self-ignition temperature is sufficient. (C 10, K 29).

46. Jones, D. T. (Imp. Chem. Ind.), British Patent 374,481 (June 13, 1932). Similar to D 44.

47. King J. G., J. Inst. Pet. Tech. 22, 595-601 (1936). Tar as a fuel. The slow-speed diesel engine requires very little adaptation to make it suitable for the combustion of heavy tar oils but these cannot be used in high-speed diesel engines, due to the difficulty of obtaining rapid ignition. Suitable means have been found for reducing ignition temperature and ignition delay of tar oils, but these are not yet a commercial proposition. Reducing ignition temperature and ignition delay of tar oils includes, (1) addition of a standard motor-fuel oil, (2) addition of a "dope" such as alkyl nitrates and nitrites (especially ethyl nitrate), and organic compounds containing a halogen atom and a nitrate group on adjacent carbon atoms. Promising results are given, (3) use of a catalytic chamber in front of the combustion chamber. (K 33).

48. Loomis, N., (Standard Oil Development Company), U. S. Patent 1,820,983 (September 1, 1931). Fuel for diesel engines. Heavy petroleum oil and 5 percent of a nitroparaffin or alkyl nitrite compound such as isopropyl nitrite.

49. Glycol nitrate, amyl nitrate (See K 36).

50. Marks, E. M. (The Atlantic Refining Company), U. S. Patent 2,244,496 (June 3, 1941). The use of nitrosites and/or nitrosates as ignition accelerators for hydrocarbon fuels of the compression-ignition type. (E 24).

51. Marvel, G. S. (Du Pont Company), U. S. Patent 2,031,497 (February 18, 1936). To increase the ignitability of diesel oils, there is added 1-5 percent of a nitric acid ester of a branched chain aliphatic alcohol, e.g., isobutyl nitrate. French Patent 370,208.

52. McCarty, W. F. C. M., U. S. Patent 1,167,770 (January 11, 1916). Composition of matter to be added to internal combustion fuels. Acetone, ether, hydrogen peroxide, and methyl nitrate, nitroglycerine. (B 35, I 21).

53. Mesurier, L. J., Inst. Petr. Tech., 17, 387, 424 (1931). Fuel tests in low and high-speed diesel engines. In general, the fuels giving the greater delay angle, i.e., the longer period between ignition and commencement of pressure rise, produced the greater combustion shock. The addition of 5 percent of amyl nitrite, a pro-knock in gasoline, or acetic acid to two fuels reduced the delay angle, and in the distillate form a mixed-base crude oil which was mainly paraffinic, induced smoothness of running. It is fairly certain that the heavy fractions of crude oils that yield explosion engine fuels of the highest antiknock value will be the worst from the standpoint of combustion shock in the diesel engine and vice versa.

54. Esters of nitric or nitrous acid. (See I 25).

55. N. V. de Bat. Petrl. Mij., French Patent 835,592 (December 26, 1938). Alphaglycerol nitrates as ignition accelerators for diesel fuels.

56. Neukom, F., British Patent 475,040 (November 8, 1937). Mentions that liquid nitro-compounds may be added to motor fuels. (E 27).

57. Nygaard, E. M. and Crandall, G. S., U. S. Patent 2,185,157 (December 26, 1939). To accelerate ignition of the fuel in an engine of the diesel type, there is mixed with it a minor proportion (suitably about 0.5 percent) of tetranitromethane.

58. Nitrates, general (See H 19).

59. Nygaard, E. M., Crandall, G. S., Berger, H. G., J. Inst. Petroleum 27, 348-68 (1941). Discussion of effect of various dopes, e.g., trichloronitromethane, alkyl nitrates and nitrites, peroxides, elementary sulfur, organic compounds in which nitrogen is linked to sulfur, (E 28, I 33, K 57).

60. Ormandy, W. R., J. Inst. of Fuel 5, No. 19, 64 (1931). "In the writer's laboratory scores of products have been tried, but nothing better than nitrobenzol, and amyl nitrate has been found." In addition of 1½ percent of nitrobenzene reduced the spontaneous-combustion temperature of a m-cresol sample by 43° C. and 1 percent of amyl nitrate lowered the spontaneous-ignition temperature 59° C. (E 29).

61. Penhale, J., British Patent 178,373 April 20, 1922). The explosive power of a fuel is increased by the addition of one of the volatile explosive compounds, e.g., ethyl or methyl nitrate, when ignited in the cylinder of an internal-combustion engine.

62. Amyl nitrate (See K 60).

63. Prettre, M., Dumanois, P., and Laffitte, P., Compt. Rend., 191, 414 (1930). Effect of amyl nitrate on thermal oxidation.

64. Progress in diesel engines and fuels during 1937. From the Annual Report of the Diesel Engine User's Association. Petroleum Times 39, No. 1007, 559-61 (1938). The spontaneous ignition temperature of a diesel-oil fraction is lowered by removing the tar acids from the fraction of the low-temperature tar distilling over between 160° and 320° C. and was reduced from 290° to 235° C. by the addition of 2 percent of chlorethyl nitrate. (K 58).

65. Ramayya, K. S., Neft. Khoz. No. 4-5, 69-79 (1937). Starting fuels for diesel engines. Addition to gasoil of ethyl nitrate, ethyl ether, chloroform, ethyl acetate, castor oil. Ethyl nitrate is the best agent. (B 40).

66. Robertson, A. F., "The Effect of Amyl Nitrate on Diesel Engine Combustion and Fuel Economy," Thesis for the Degree of Doctor of Philosophy, University of Wisconsin (1940).

67. Roth, K., German Patent 164,634 and 164,635 (October 7, 1903). Ignition accelerators. Picric acid, ammonium nitrate, nitromethane, nitroethane, nitro and dinitrobenzene, nitroglycerine, nitrophenol, dinitronaphthalene, dinitrotoluene, dinitrocellulose; 5 percent added to motor fuel. (B 45, E 31).

68. Schaad, R. E. and Boord, C. E., Ind. Eng. Chem. 21, 756 (1929). Ignition due to hot surface easier when isoamyl nitrate is added.

69. Selden, R. F., N.A.C.A. Tech. Note No. 710 (1939). Use of isoamyl nitrate as combustion accelerator in fuel shows ignition lag comparable with other fuels having same cetane number.

70. Sims, J. C., British Patent 294,129 (July 16, 1928). "Various classes of chemical compounds can be used as the primer, such as nitro compounds (trinitroresorcinol), nitrous and nitric acid esters, azo compounds, haloid compounds, chlorates and organic perchlorates, acetylenic compounds, superoxides, nitroamines or other compounds which liberate free oxygen on disruption. The quantity required is small, about 5 percent by volume." (I 43, K 68).

71. Nitro compounds, general (See F 5).

72. S.A.L.N.A.; Soc. anon. Lav. Nafte. Italian Patent 309,329 (1936). Motor fuels, mixtures of benzine and benzene have ignition quality raised by the addition of nitrated polyhydric alcohols, such as nitropentaerythrite.

73. Standard Oil Development Company, British Patent 535,401 (April 8, 1941). Alkyl nitrate (cetyl, decyl, dodecyl nitrate, oxidized wax alcohol nitrate) added to diesel fuels as ignition promoters and a small amount of trialkylamine as additional compound. (K 75).

74. Standard Oil Development Company, British Patent 520,568 (April 26, 1940); C. A. 36, 6408 (1942). Diesel fuels are improved by adding 0.25-3 percent of ignition promoters consisting of compounds with groupings containing O_2, N, and S attached to C. The use of organic (branched alkyl) thionitrites, sulfonium nitrates, and sulfonylhydroxylamines is claimed, and the use and preparation of dibutyl-SNO from butyl mercaptan and NOCl at —5° to —10° are described. (K 76).

75. Standard Oil Development Company, British Patent 543, 669 (March 9, 1942). An improved diesel fuel is obtained by adding a small proportion of a nitroalkyl nitrate to a hydrocarbon fuel.

76. Ethyl nitrate, nitro compounds (See K 79).

77. Stansfield, R., Proc. World Petr. Congress Sect. 2, 256-61 (1932). Five percent of ethyl nitrate added to a 42-cetane fuel improved the starting quality. Further, dopes such as ethyl nitrate are more effective under full load and the fuels doped in this way are quite susceptible to engine conditions. To illustrate, a 42-cetane fuel doped with 1 percent of ethyl nitrate rated 49-cetane at 68° F. jacket temperature, 53- cetane at 140° F. and 61-cetane at 212° F.

78. Isoamyl nitrate, ethyl nitrate (See I 49).

79. Tetranitromethane (See E 41).

80. Tixier, A., and Crussaire, A. G. J. French Patent 547,930 (December 28, 1922). A substance generating energy such as methyl nitrate, nitrated derivatives, nitric ethers, etc., is added to ordinary fuel to increase the power of explosion motors.

81. Vanderbilt, B. M. (Standard Oil Development Company), U. S. Patent

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2,241,492 (May 13, 1941). Nitroalkyl mononitrates are apparently as effective as acetone peroxide, from the increases in cetane number quoted. Examples of the nitro-1-propanol (most effective), and 2-nitro-1-butanol.

82. Nitro compounds (See B 59).
83. Nitrites, general (See B 60).
84. Weber, M. E., Belgian Patent 405,078 (October 31, 1934). Liquid fuel for heat engines. Liquid nitrated hydrocarbons, e.g., isopropyl nitrate and nitroethane.
85. Weber, P., Oel u. Kohle. 36, 73-89 (1940); J. Inst. Petroleum 26, 382A (1940). Cetane number dopes such as amyl nitrate had not correspondingly good effects on the starting temperature so the relationship established between starting temperature and cetane numbers of diesel fuels does not hold if the latter are doped.
86. Whitman, W. G., Ind. Eng., Chem. 33, No. 7, 866 (1941). Amyl nitrate and organic polysulfides raise the cetane number of diesel fuels. (J 22).
87. Winand, P., British Patent 24,090 (January 17, 1907). Fuel oils. Non-explosive liquid nitro compounds of carbon are used in engines as fuels and as oxygen carriers. Tetranitromethane and oils.
88. Withers, J. G., J. Inst. Petr. Tech. 19, 713 (1933). The following data show the effect of ethyl nitrate when added to diesel fuels in amounts from 1 to 4 percent. Three base fuels were used.

Fuel No.	Delay Angle in Degrees for Various Additions of Ethyl Nitrate				
	0%	1%	2%	3%	4%
1	10.00	9.00	8.50	8.25	8.00
2	18.00	14.00	12.50	11.50	11.00
3	21.00	17.00	13.00	11.00	9.50
1*	10.00	12.50	14.50	17.00	19.00

*T.E.L. added instead of ethyl nitrate.

Five percent of amyl nitrite reduced delay from 10° to 7° and the shock noise from 190 strobophonometer noise units to 70 units.

89. Nitrated hydrocarbon (See H 27).
90. Woods, G. M., Pet. Eng. 8, No. 2, 90 and 8, No. 3, 58 (November, 1936). Ignition quality is improved by the addition of dopes; organic nitrates seem satisfactory and useful. (E 42).
91. Nitrates of an aliphatic polyhydric alcohol (See B 61).
92. Wyler, J. A. (Trojan Powder Company), U. S. Patent 2,270,400 (January 20, 1942); C. A. 36, 3345[8], (1942). For accelerating the ignition of a fuel which is spontaneously ignited on injection into compressed air in an engine cylinder, the fuel is preliminarily mixed with about 0.5-1.5 percent of tetranitromethane.

E. Aromatic Nitro Compounds

1. Ackerman, A. H., U. S. Patent 1,653,032 (December 20, 1927). Motor fuel. Naphthalene, nitrobenzene, etc., are added
2. Picric acid, nitronaphthalene (See I 1).
3. Basset, Harry P., U. S. Patent 1,641,520 (September 6, 1927). Aminonitro mixtures such as aniline and nitrotoluene are added to a fuel; the amino compound acts as a combustion retarder and the nitro compound serves as a "sensitizer or combustion propagator."
4. Trichloronitromethane (See K 7).
5. Cia Italiana Sirluppo Anvent. S. A. and Gallarati, V., British Patent 358,484 (October 5, 1931). The addition of bodies containing one or more nitro groups to motor fuels. Nitroglycerine, nitroguanidine, nitrocellulose, trinitrophenol, trinitrotoluene, etc. Also Norwegion Patent 51, 574 (1932). (B 12).
6. Nitronaphthalene (See D 16).
7. Costaguta, D., British Patent 253,353 (June 17, 1926); French Patent 599,271 (1925). Means of increasing the fuel value of motor fuels. The use of a mixture containing nitrophenol derivatives, e.g., trinitrophenol, ethers and liquid hydrocarbons; 4.5 percent of the mixture is added to the motor fuel. (B 14).
8. Cransioe, Daniel, Danish Patent 21,091 (1916). Liquid fuel for internal-combustion motors consisting of alcohol and benzol characterized by addition of a small amount (0.1 percent) of picric acid or an equivalent material or an organic nitrate, e.g., from an alcohol radical from the aliphatic group as nitroglycerine or a nitro combination of hydroaromatic or similar materials. Also Swedish Patent 45, 049 (1914). (B 15).
9. Nitrates and picrates of the benzol or the naphthalene series (See H 5).
10. Hadorff, K., British Patent 10,739 (May 2, 1911); German Patent 229,579 (February 1, 1911). Oils for burning. A mixture of benzene picrate with petroleum, etc., as a fuel for internal-combustion engines
11. Nitrotoluene, dinitrobenzene, nitroaniline (see K 23).
12. Dinitrobenzene, picric acid, trinitrotoluene (See D 31).
13. Organic polynitro compound (See D 34).
14. Nitrocompounds, general (See H 8).
15. Nitro products of hydroaromatic hydrocarbons (See D 36).
16. I. G. Farbenindustrie A.-G., German Patent 518,232 (July 24, 1933). Addition to Patent 508,917; C. A. 28, 1181 (1934). The method of Patent 508,917 for improving diesel fuels by means of soluble organic compounds of the C_6H_5 series containing O or N but no halogen.
17. Isermann, S., Vernet, W., and Moses, E. A. (Pat. Fuels and Color Company); Canadian Patent 311,315 (May 12, 1931). Benzine and 0.12 percent of o-nitrotoluene and 0.001 percent of 1,4-ditoluidineanthraquinone.
18. Nitrobenzene (See K 36).
19. Jensen, W. D., U. S. Patent 2,146,742 (February 14, 1939). Fuel for internal combustion engines. 0.05 percent of dinitrophenol is mixed with petroleum distillate, to improve combustion.
20. Levi, L. E., U. S. Patent 2,062,463 (December 1, 1936). The combustion of fuels improved by adding 1 percent of a solution of dinitrobenzene in methyl formulate or oxalate. Aldehydes or carboxylic acids may be added. (B 30).
21. Picric acid (See F 4).
22. Mancini, A., British Patent 131,869 (1919). Explosive mixtures for internal combustion engines. Use of nitro derivatives, e.g., nitrobenzene, nitrotoluene, nitroxylene, nitronaphthalene, nitroaniline. French Patent 496,099.
23. de Mare, F., British Patent 3626, (June 11, 1903). Use of nitrobenzene.
24. Nitro compounds, general (See D 50).
25. Nitrobenzene (See B 34).
26. Mellersh-Jackson, L., (H/H Oil Company A/S), British Patent 350,440 (June 8, 1931). Improved fuel in respect to the perfect combustion in the cylinder is attained by adding to aliphatic hydrocarbons a quantity of aromatic hydrocarbons treated with nitric acid and subsequently with sulfuric acid, the mixture being subsequently treated with oxygen or ozone. The acid treatment is carried out at a substantially low temperature whereby no nitro compounds are formed. (H 6).
27. Liquid nitro compounds (See D 56).
28. Trichloronitromethane (See D 59).
29. Nitrobenzol (See D 60).
30. Chloropicrin (See K 60).
31. Picric acid, nitro and dinitrobenzene, nitrophenol, dinitronaphthalene, dinitrotoluene. (See D 67).
32. Picrate of a hydrocarbon (See I 40).
33. Nitrobenzene (See I 41).
34. Naphthalene picrate (See I 42).
35. Soc. Exp. Brevets d'Inventions, S.E.B.I., French Patent 717,817 (1931). Heavy mineral or vegetable oils are made suitable for motor fuels by the addition of an activator: a mixture of a diazo derivative with a nitro derivative, or a hydrazo derivative with a poly-nitro derivative. Also Netherlands Patent 30,568, British Patent 379,725 (August 29, 1932).
36. Nitro compounds (See K 79).
37. Tunison, B. R., U. S. Patent 1,423,050 (July 18, 1922). The use is proposed of nitrobenzol, nitrotoluol or nitroxylol as fuel improvers for fuels, to be used under steam boilers or in diesel engines. As an example, 5 parts of nitrobenzol are mixed with 20 parts of benzol and 75 parts of heavy oil but any of the materials mentioned above could be substituted for the nitrobenzol.
38. U. S. Industrial Alcohol Company, Norwegion Patent 34,501 (1922). Fuel consisting of a petroleum distillate and an alcohol by adding, to cause a mixture, an aromatic nitrate, e.g., nitrotoluol. (B 57).
39. U. S. Industrial Alcohol Company, British Patent 140,796 (1920), French Patent 92,691 (1922). A distillate such as gasoline or kerosine, an alcohol, and a nitrated aromatic compound such as nitrobenzene are mixed for a fuel. (B 57).
40. Explosives (See B 60).
41. Winand, P., German Patent 188,100 (November 2, 1905); U. S. Patent 914,624 (March 9, 1909). Employs as an oxygen carrier such nitrated carbon compounds as contain a large proportion of carbon with respect to the hydrogen present and a smaller proportion of oxygen, e.g., the mono-, di- and trinitrobenzols, or such nitrated carbon compounds as contain a large proportion of nitrogen in comparison to the carbon present, e.g., tetranitromethane. (D 79).
42. Organic nitro compounds (See D 90).

F. Nitration

1. Ellis, Carleton (Standard Oil Development Company), U. S. Patent 2,240,558 (May 6, 1941). Ignition temperature of diesel fuel is lowered by treating the fuel with nitric acid or mixtures of concentrated sulfuric and nitric acids, sulfuric acid and sodium nitrate, or the oxides of nitrogen.
2. Grevel, A., German Patent 379,966 (August 31, 1923). The gasoil fraction of crude oil, b.p. 180°-360° C., is mixed with nitric acid, nitrated, and refined.
3. Hense, R., French Patent 618,302 (March 9, 1926) B.C.A.-B. 7 (1928). For increased engine efficiency and complete combustion in explosion motors, appropriate acids such as nitric and sulfuric acid are added to hydrocarbon mixtures, the mixture being stirred continually, purified, and distilled. The hydrocarbons are mixed with petroleum fractions and ammonium nitrate is formed by neutralizing the nitric acid with ammonia.
4. Luck, C. E. Courtney, British Patent 12,059 (May 21, 1914). Treating and cracking oils. Heated paraffin oil is contacted with a nitro compound at distilling temperatures, to crack the same. Manufacture of liquid combustible fuel for internal-combustion engines by fractionally distilling a mixture of petroleum of sp. gr. 0.805 (not above), a gum resin, benzene, and picric acid. (E 21).
5. Soc. Exp. Brevets d'Inventions, S.E.B.I., British Patent 379,725 (August 29, 1932). Heavy oil such as derived from petroleum, shale, asphalt, lignite, or peat is rendered suitable for diesel fuel by mixing, after refining, with an activator prepared by treating with a nitrating agent the residues obtained during the sulfuric-acid refining of said oils and then partly reducing the obtained nitro compounds with nascent hydrogen to obtain a mixture of nitro, diazo, azo and hydrazo compounds. (D 71, K 69).
6. Standard Oil Development Company, British Patent 491,648 (September 5, 1938). Diesel fuels of low ignition temperature, are obtained by treating a heavy petroleum oil with a nitrating agent. A nitrating catalyst, aluminum nitrate, may be added to the nitrating stage. Nitrated primers may be extracted with a solvent (aniline). Use of nitric acid with water in nitrating α-naphthol may be added.
7. Standard Oil Development Company, French Patent 817,379 (September 1, 1937); C. A. 32, 2717 (1938). Diesel fuel is treated with a nitrating mixture or HNO_3 diluted with water approximately to the point corresponding to the minimum formation of mud, and acid and acid material are eliminated. The product is of higher density and takes fire at a lower temperature than the original fuel.
8. Urbanski, T., and Slon, M., Roczniki Chem. 17, 161-4 (1937); C. A. 31, 6190 (1937). Process for the nitration of paraffin hydrocarbons.
9. Wingett, J. N., U. S. Patent 1,185,747 (June 6, 1916). Manufacturing combustion or power liquids. Adding an oil normally nonsensitive to ignition at low temperatures, a coal distillate and a nitrating solution and distilling the mixture so formed to reduce the flash and ignition point of the product.

G. Oximes and Nitroso Compounds

1. DuPont Company, British Patent 429,763 (June 6, 1935). A fuel oil for a diesel engine in which has been dissolved as a primer a nonaromatic organic compound containing an oxime group (-NOH), in the amount of 1-5 percent. Examples of suitable primers are: formaldoxime, acetaldoxime, butyraldoxime, methylethyl ketoxime, glyoxime, cyclopentanone oxime, etc.
2. Nitrosomethylurethane (See D 27).
3. Howes, D. A. (Imp. Chem. Ind.), British Patent 405,658 (August 5, 1934); B.C.A.-B. 311 (1934). Fuel for diesel motors. The fuel oil is primed by dissolving therein 1 to 5 percent of a non-explosive aliphatic or aromatic heterocyclic nitroso-compound. For example, 1 percent of nitrosotriacetonamine, nitrosonaphthylmethyl- nitrosonaphthylethyl- urethanes is dissolved in the oil fraction boiling up to 300° obtained in the destructive hydrogenation of coal.
4. Salzberg, P. L., and Peterson, W. R. (DuPont Company), U. S. Patent 2,009,818 (July 30, 1935). The delay period between injection and ignition of a fuel is reduced by the addition of organic compounds containing either a nitroso or an oxime group. The structure and constitution of the nitroso and oxime compounds are capable of considerable modification, e.g., they may be either aliphatic or heterocyclic; the oximes may be aldoximes or ketoximes, etc.

H. Oxidation and Oxidation Products

1. Blum, Richard, German Patent 324,294 (August 24, 1920). Ozone, ozonized air, or ozonides are added to fuel mixtures in solid, oily, or gaseous form.
2. Broche, H., Gluckauf, 68, 965-82 (1932). The use of tar oils in diesel engines. Oxidation catalysts and oxygen, vanadium pentoxide, etc. (C 2).
3. Bruzac, J. F. A., French Patent 689,021 (January 28, 1930); C. A. 25, 1060 (1931). A fuel suitable for diesel engines is made by treating crude petroleum, schist oils, lignite oils, etc., with ozonized air or ozone.

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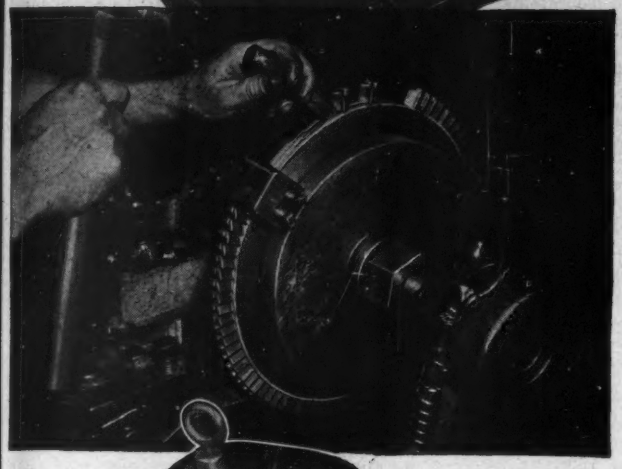
4. Csanyi, H., U. S. Patent 1,333,837 (March 16, 1920); C. A. **14**, 1437 (1920). In order to increase the proportion of oxygen in explosion mixtures, hydrocarbon vapor and moisture are subjected to electrolysis while being led to the point of combustion in order to decompose the water in the mixture and augment the proportion of oxygen in the mixture. British Patent 129,010 (1917).
5. Greenstreet, C. J., U. S. Patent 1,800,997 (April 14, 1931). This invention relates to a process of refining diesel fuels so that they will carry a substantial quantity of their own oxygen. For example, with kerosine made by pressure distillation, air is blown through and afterwards air-agitated with from 1 to 3 percent by volume of the active oxygen agent; said agent being the product resulting from decomposing the percarbonates, persulfates, perborates or dioxides with acid, and carrying approximately 8 to 10 volumes of oxygen in solution, or the equivalent in gaseous form. The combustible oxygen-carrying materials or oxidizing materials are well-known. Nitrates and nitrating compounds can be used; the products resulting from decomposing percarbonates, persulfates, perborates and dioxides with acids above-mentioned or any oxygen-carrying compound which will give up its oxygen under engine-cylinder temperatures when carried in an explosive mixture, the mixture being benefited and even greater power obtained if used in proper proportions with the nitrates and picrates of the benzol, or the naphthalene series, or with combustible liquids, partially oxidized, such as the alcohols. (B 21, D 24, E 9).
6. Treatment with oxygen or ozone (See E 26).
7. Quinonic oxidation compounds (See B 22).
8. Hense, R. (additional), British Patent 14,671 (1907). Mineral oils (raw naphtha) are treated to obtain fuel oils while simultaneously increasing the dynamic energy of the fuels. Addition to mineral oils of dissolved bodies containing carbon products volatilized with difficulty, salts rich in oxygen, also nitro bodies soluble in mineral oils and distilling the mixture with super-heated steam. Peroxides may be used. (D 35, E 14, I 17).
9. I. G. Farbenindustrie, A.-G., French Patent 825,113 (February 24, 1938); C. A. **33**, 3467 (1939). To increase the ignition speed of brown-coal dust, such as fuel for dust motors, they are treated with oxides of nitrogen, obtained by catalytic combustion of ammonia, etc.
10. Johnson, J. Y. (I. G. Farbenindustrie, A.-G.), British Patent 319,853 (July 14, 1928); B.C.A.-B. 968 (1929). The use of oxygen in diesel engine operation. Powdered fuel used with oxygen or air containing additional oxygen.
11. Oxygen-containing aromatics (See A 8).
12. Laurent, A., French Patent 615,750 (May 7, 1926); B.C.A.-B. 835 (1927). Addition of ozone or ozonides to hydrocarbons.
13. Lintz, O., British Patent 1,103 (1906). Fuel oils. Liquid fuel such as petroleum is saturated with air or oxygen prior to admission to the diesel engine.
14. Mardles, E. W. J., Science of Petroleum, 4, 3034-3035 (1938). Oxidants and Antioxidants in the Petroleum Industry.
15. Martini, D., British Patent 13,840 (June 16, 1906); C. A. **1**, 2642 (1907). Ionization of the oxygen of the air and its use to form ionic nuclei with a spray of crude petroleum or its distillates for internal-combustion engines.
16. Meyer, E. G., British Patent 262,363 (June 12, 1926); B.C.A.-B. 134 (1927). Similar to H 14.
17. Moore, C. M., (Union Oil Company of California), U. S. Patent 2,146,265 (February 7, 1939). Ozone-containing gas used as diesel ignition accelerator.
18. Noteman, A., U. S. Patent 512,894 (January 16, 1894). Impregnation of hydrocarbon oils with oxygen or an agent rich in oxygen.
19. Olauson, E. A., Swedish Patent 75,292 (November 24, 1927-November 1, 1932); Chem. zentr. pt. II, 384 (1934). Starting cartridges for oil motors. Use of combustible substances and materials giving off oxygen, sulfur and nitrates, chlorates, or perchlorates. (D 58, K 56).
20. Oliviero, M. J., French Patent 777,917 (March 5, 1935); C. A. **29**, 4552[7] (1935). Combustion improved by using ozonized air.
21. Pfirrman, T. W. (To Friedrich Uhde), U. S. Patent 2,213,407 (September 3, 1940); C. A. **35**, 602 (1941). A process for making difficultly ignitable diesel-power fuels more readily ignitable, which comprisies treating such a fuel in the liquid phase with a gas comprising O_2 in such proportions and for such a reaction period that no substantial proportions of O_2-containing hydrocarbon compounds are formed, and the boiling curve of the distillable portion of the starting material is not substantially altered, the treatment taking place between 150° and 350°. (British Patent 499,372).
22. Ramage, A. S., British Patent 273,832 (April 13, 1926); B.C.A.-B. 661 (1927). Ozonides. Olefinic materials treated with ozone at 30°-40° below the boiling point to obtain motor fuels.
23. Schultz, T. H., Levine, I. E., and Wellman, H. B., (Standard Oil Company of California), U. S. Patent 2,317,968 (April 27, 1943). A process is employed for preparing a diesel-type motor fuel containing substantial proportions of chemically combined reactive oxygen, directly measurable in terms of oxygen factor of the fuel.
24. Oxidation (See B 49).
25. Stryker, D., Canadian Patent 306,144 (November 25, 1930); C. A. **25**, 798 (1931). Motor fuel. Liquid hydrocarbon fuel and less than 1 percent of oxidized heavier hydrocarbons soluble therein. Higher fatty acids may be mixed with the mineral oils.
26. Vyrubov, D. N., Dizelestonenie No. 7, 3-10 (1940); Khim. Referat. Zhur. **4**, 15 (1941). Addition of O_2 decreases the arrest in the explosion and increases the velocity of combustion. Ozone has no effect on the combustion process within the limits of the concentrations (0.001-0.0015 percent in the air used) and pressures used. Additions of H_2 retard the explosion, decreasing the oxidation velocity of the process.
27. Wolff, Max & Company, m.b.H. French Patent 705,958 (February 5, 1930); C. A. **26**, 283 (1932). Hydrocarbon motor fuels improved by adding a support for oxygen which is enriched in oxygen before or after addition to the fuel. Thus a nitrated hydrocarbon or a hydrocarbon of the terpene series (oil of turpentine) is added to a hydrocarbon fuel and oxygen or ozone is passed through the fuel. British Patent 376,286 (1932). (D 89).
28. Ueda, K., Japanese Patent 101,726 (1933). Fuel for diesel engines. The oil is treated with chromic acid mixture in the presence of active carbon.

I. Peroxides

1. Anon., Am. Gas Light Journal **102**, 183 (1915). Peroxidized kerosine as a motor fuel. Kerosine and other heavy petroleum oils are mixed with a small amount of peroxides, picric acid or nitronaphthalene. (E 2).
2. Alkyl peroxides (See B 4).
3. Peroxides of ketones and peroxides of anhydrides from fatty acids (See D 5).
4. Badertscher, D. E., and Crandall, G. S. (Socony-Vacuum Oil Company), U. S. Patent 2,174,680 (October 3, 1939). Diacetal peroxide as a diesel dope. Acetic anhydride is added to the oil and then oxidized in situ to diacetal peroxide. One percent goes from 42 to 59 or an increase of 17.0. Other blends show increases as low as 3-5 cetane numbers for 1 percent in a 42-cetane stock.
5. Broeze, J. J. and Hinze, J. O., "Experiments with Doped Fuels for High Speed Diesel Engines." Paper presented at World Automotive Engineering Congress of the S.A.E. at New York City. (May 22, 1939). J.I.P. **25**, 657-77 (1939). Reference is made to acetone peroxide and ethyl nitrate. (D 9).
6. Buerk, G., U. S. Patent 1,766,501 (June 24, 1930). Liquid fuel for internal-combustion engines. Gasoline, benzol, naphtha, kerosine, crude oil or crude oil derivatives have added 0.5 percent of benzoyl peroxide, hydrogen peroxide, naphthalene peroxide, or per salts to give greater explosive effect and greater power.
7. Aromatic peroxides (See D 15).
8. Egerton, A. C., Cong. Chim. Ind.C.r. 18me Cong. Nancy 1123-1132 (September-October, 1938). The importance of peroxides in the combustion of hydrocarbons.
9. Egerton, A. C., British Patent 443,562 (March 2, 1936); U. S. Patent 2,093,008 (September 14, 1937). Diesel or other engine fuel is doped with a peroxide in which one of the peroxide atoms is attached to an alkyl or aryl-alkyl radical while the other is attached to hydrogen or a second alkyl radical, e.g., diethyl peroxide. Alkylidient peroxides also may be used.
10. Egerton, A. and Ubbelohde, A. R., Nature **133**, 179 (1934); C. A. **28**, 2512 (1934). Et_2O_2 is a violent pro-knock, slightly more potent than $C_5H_{11}NO_2$ at the same concentration. Its knocking action is inhibited by $PbEt_4$. $EtHO_2$ is likewise definitely a pro-knock. In spite of the ease of thermal decomposition, H_2O_2 has a definite but slight pro-knock tendency.
11. Elkington, H. (N.V. de Bat. Petr. Maat.), British Patent 428,972 (May 16, 1934), German Patent 617,492 (August 20, 1935). Diesel fuels. Fuel is primed with acetone peroxide, with or without tetrahydronaphthalene peroxides, nitrogen sulfide (N_4S_4) or esters of nitric or nitrous acid; up to 5 percent is added. D 19, J 7).
12. Harnor, W. A., Chem. News **20**, No. 2, 91 (1942). Acetylbenzoyl peroxide displayed a higher activity as a diesel dope than diacetone dipedoxide when added to commercial gasoil.
13. Tetralinperoxide (See D 27).
14. Peroxides, general (See D 29).
15. Benzoylperoxide, amylene peroxide (See D 31).
16. A peroxide of an organic substance (See D 34).
17. Peroxides, general (See H 8).
18. Hock, H., German Patent 651,771 (October 19, 1937). The ignition point of a diesel oil is improved by adding 1-3 percent of tetrahydronaphthalene peroxide.
19. Kokatnur, V. R. (Autoxygen, Inc.), U. S. Patent 2,296,558 (September 22, 1942). This invention relates to a diesel fuel containing lauroyl peroxide in sufficient amount to increase the cetane number of the fuel base.
20. Krepelka, J. H., and Buksa, R., Chem. Listy. **31**, 447-55 (1937). New addition compounds of hydrogen peroxide with organic compounds.
21. Hydrogen peroxide (See D 52).
22. Moser, F. R. (Shell Development Company), U. S. Patent 2,011,297 (August 13, 1935); Canadian Patent 349,965 (April 30, 1935). A small amount of tetralinperoxide (0.5 to 1.5 percent) is added to fuel for internal combustion engines.
23. Moser, F. R. (Shell Development Company), Canadian Patent 355,519 (January 21, 1936); C. A. **30**, 2747 (1936). A motor fuel for a diesel engine containing a small amount of a compound selected from the class consisting of ketone and aldehyde peroxides, e.g., acetone peroxide.
24. Moser, F. R. (Shell Development Company), U. S. Patent 2,218,135 (October 15, 1940). A small proportion of methylethyl ketone peroxide or the like (suitably about 0.5-1 percent) is added, and serves to give improved ignition properties.
25. Moser, F. R. (Shell Development Company), U. S. Patent 2,107,059 (February 1, 1938). Acetone peroxide alone and acetone peroxide plus a substance selected from the group consisting of tetralinperoxide, nitrogen sulfide, esters of nitric or nitrous acid as ignition accelerators. (D 54, K 51.)
26. Moser, F. R. (Shell Development Company), U. S. Patent 2,133,733 (October 18, 1938); C. A. **33**, 837 (1939). An aldehyde peroxide or ketone peroxide such as acetone peroxide is used with a minor proportion (10-50 percent) of a hydrocarbon material such as gasoil in a liquid state sufficient to wet the peroxide surfaces and serving to facilitate safe handling of the product.
27. Moser, F. R. (Shell Development Company), U. S. Patent 2,092,322 (September 7, 1937); C. A. **31**, 7883 (1937). A ketone or aldehyde such as acetone is caused to react with a persulfate-radical containing solution which has been subject to a hydrolytic treatment to produce an organic peroxide such as acetone peroxide.
28. Moser, F. R. (Shell Development Company), U. S. Patent 2,240,145 (April 29, 1941). A liquid fuel for compression-ignition engines containing a small amount of heteropolymeric ketone peroxides obtained by oxidizing a mixture of at least 2 ketones of different molecular sizes, one of which is acetone. This invention is an improvement over that disclosed in U. S. Patent 2,011,297.
29. N. V. de Bat. Petr. Maat., British Patent 421,928 (January 26, 1934); B.C. A.-B. 216 (1935). Liquid fuel for diesel engines is primed by dissolving therein one or more organic peroxides or mixtures containing such peroxides, or by forming such peroxides therein, no other primer being present. As an example, 0.5 to 1.5 percent of tetrahydronaphthalene peroxide is cited.
30. N. V. de Bat. Petr. Maat., British Patent 444,544 (September 11, 1935); B.C. A.-B. 683 (1936). Diesel fuels. The ignition quality of diesel fuels is improved by adding acetone peroxide or its homologues, e.g., peroxides, of methylethyl ketone, diethyl ketone, diisopropyl ketone, etc.
31. N. V. de Bat. Petr. Maat., German Patent 617,492 (August 20, 1935). Similar to I 30.
32. N. V. de Bat. Petr. Maat., French Patent 774,099 (1934). Similar to I 11.
33. Peroxides, general (See D 59).
34. Oosterhuis, Albert G., Jr., French Patent 821,747 (December 11, 1937); C. A. **32**, 3769[3] (1938). Aromatic peroxides. Peroxides insoluble in water are prepared from an acid chloride and an alkaline solution of a peroxide in the presence of a dispersing agent for the acid chloride, e.g., oleic or ricinoleic acid, Turkey-red oil, sodium taurocholate, saponin or lechithin.
35. Pevere, E. F., and Meyer, W. N., (The Texas Company), U. S. Patent 2,178,327 (October 31, 1939), C. A. **34**, 1466 (1940). About 1-5 percent of dipropionyl perox-

Controlled drive fitting needed here – tolerance .00025!"



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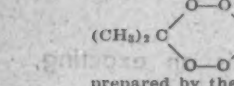
ide is added to improve the ignition characteristics of the fuel. Other compounds in the same class are diacetal peroxide and dibutyryl peroxide.

36. Pickard, W., British Patent 106,637 (October 26, 1916); C. A. 11, 2607 (1917). Solid fuel for internal-combustion engines; powdered coal dust and manganese dioxide or sodium peroxide. (C 18).
37. von Richter, V., "Organic Chemistry," Blakiston's Son & Co., London, 1919, Vol. I. 224, Cyclodiacetone peroxide



prepared by the action of H_2SO_5 (Caro's acid) on acetone (B. 33, 858). Cyclotriacetone peroxide $(C_3H_6O_2)_3$, m.p. 97°, is obtained from acetone and hydrogen peroxide, with special ease when in the presence of hydrochloric acid. It is insoluble in water, but soluble in benzene and in ether. It explodes when struck or suddenly heated (B. 28, 2265). Methyl ethyl ketone and H_2SO_5 produce methyl ethyl ketone peroxide $(C_4H_8O_2)_2$, a colorless oil, which explodes above 100°.
38. Schmidt, A. W., Braunkohlen 35 535-48 (1936). Evaluation of fuels. Anti-knock tests. Effects of addition of benzene and alcohol. Addition of organic peroxides—ignition effects as pro-knock agents for diesel fuels. Divided into dialkyl- and ethylidene peroxides, the most efficient with oils from brown and bituminous coals and with petroleum gasoil were those with oxygen entirely in peroxide combination. Best in order: dimethyldiethyl-, diacetoxydiethyl- and ethylidene, acetyl-, benzoyl- and tetralinperoxide.
39. Schmidt, A. W., and Mohry, F., Oel u. Kohle ver. Petroleum 36, 122-8 (1940); C. A. 35, 297 (1941). Results show that the ignition delay of the low-temperature carbonization fuels is increasingly improved by the addition of tetralin peroxide, acetyl benzoyl peroxide, monohydroxydiethyl peroxide, ethylene peroxide, diacetone diperoxide, diethylperoxide, and dimethyl peroxide in the order indicated. Acetyl benzoyl peroxide showed higher activity than diacetone diperoxide when added to commercial gasoil. Quality increases in power output were observed.
40. Selden, G. B., U. S. Patent 928,803 (July 20, 1909). Picrate or aromatic hydrocarbon alone or in admixture with a peroxide for use in improving ignition quality for diesel fuels. (E 32).
41. Selden, G. B., U. S. Patent 929,503 (July 27, 1909). More power is obtained from an engine when 1-2 percent of nitrobenzene and 0.5 percent of a volatilizable peroxide such as hydrogen peroxide or benzoic or acetic peroxides is added to the hydrocarbon fuel. (E 33)
42. Selden, G. B., National Petroleum News 5, No. 7, 39-42 (1913). Peroxidized kerosine. Absorption of hydrogen peroxide and organic peroxides. An increase in power is obtained by adding peroxides and naphthalene picrate to fuel oils. (E 34)
43. Peroxides, general (See D 70).
44. Standard Oil Development Company, British Patent 545,125 (May 12, 1942). A diesel fuel containing from 0.5 to 4 percent of diacyl peroxide (dilauroyl peroxide).
45. Peroxides, general (See K 79).
46. Tadema, Harco J. (Shell Development Company), U. S. Patent 2,270,175 (January 13, 1942); C. A. 36, 3345[9], (1942). Aliphatic ketone peroxides and mixtures containing them are obtained by treating aliphatic ketones such as acetone with products of incomplete combustion of hydrocarbons, the products obtained being suitable additions for improving the ignition properties of diesel fuels.
47. Texaco Development Corporation, French Patent 817,326 (February 3, 1937); Chem. Zentr. pt. I, 512 (1938). The ignition velocity of diesel oils is increased, if 1-5 percent, especially 3-4 percent, of a peroxide of a ketone with 3-6 carbon atoms are added. Peroxides of methylethyl ketone, methylpropyl ketone, diethyl ketone.
48. Texaco Development Corporation, British Patent 488,625 (July 11, 1938); C. A. 33, 347 (1939). Diesel fuels are primed by adding a small proportion, e.g., 1-5 percent, of a peroxide of an aliphatic ketone containing in the unimol. form 4-5 C atoms. The cetene number is raised.
49. Thiemann, A. E., Automobiltechnische Zeitschrift 45, 454-7 (1942); Chem. Zentr. 2, 2757 (1942). Several ignition accelerators are mentioned: ketone or aldehyde peroxides which result from the action of hydrogen peroxide upon aldehydes and ketones or by extraction with oil from a mixture of sulfurous and persulfuric acid as well as ketones; acetone peroxide, other ketone peroxides, isoamyl nitrate, tetranitromethane, ethyl nitrate and alcohol. (B 55 D 78)

J. Polysulfides

1. Berger, H. G., George, R. S., and Nygaard, E. M., U. S. Patent 2,206,594 (July 2, 1940); J. Inst. Petroleum 423A (1940). Preparation of an improved diesel fuel composed of a hydrocarbon fuel oil and a minor proportion of hydrogen persulfides and elementary sulfur in admixture therewith. (K 4)
2. Bosch, A. G., British Patent 316,055 (July 25, 1929). Igniting composition for starting cold crude-oil engines. A Cartridge comprising a phosphorous compound, such as phosphorous sesquisulfide.
3. Polysulfides, general (See D 15).
4. Cloud, G. H., and Mikeska, L. A., (Standard Oil Development Company), U. S. Patent 2,268,382 (December 30, 1941); C. A. 36, 2708[7], (1942) For improving its ignition properties a hydrocarbon fuel is mixed with about 1-5 percent of sulfocarboxylethyl disulfide or other organic compound containing a thiocarboxylic acid radical. U.S.P. 2,268,384—relates to like use of about 1-5 percent of tetramethyl thiuram disulfide or other organic compound containing an active thiocarboxylic acid radical and N. Miller, P., and Cloud, G. H., U.S.P. 2,268,383 (December 30, 1941) relates to liquid hydrocarbon diesel fuels boiling above 400° F. and prepared with the addition of about 0.025 percent or more of added free S which may be present in a free and loosely combined form, for improving the ignition properties of the fuel. (K 11)
5. Cloud, G. H. (Standard Oil Development Company), U. S. Patent 2,263,234 (December 30, 1941). For high-speed operation, a hydrocarbon diesel fuel is blended with about 0.25-5 percent by volume of alkyl trisulfide such as diamyl trisulfide to improve ignition quality.
6. Crandall, G. S., and James, W. H., U. S. Patent 2,164,151 (June 27, 1939). A hydrocarbon fuel oil is used with an admixture of about 0.5 percent or more of a bis (aminoaryl) disulfide such as aniline disulfide or o-toluidine disulfide which serves to give improved ignition properties.
7. Nitrogen sulfide (See I 11).
8. Diethyl tetrasulfide (See D 27).
9. Polysulfides, general (See D 29).
10. James, W. H., Moran, R. C., and Nygaard, E. M., (Socony-Vacuum Oil Company), U. S. Patent 2,177,719 (October 31, 1939). (bis) Diamylamine disulfide, used as a diesel dope, shows about 6-cetane rise for 0.5 percent by weight in a 47-cetane stock.
11. Maverick, G. M. (Standard Oil Development Company), U. S. Patent 2,045,788 (June 30, 1936). Motor fuel for diesel engines. The major portion is a light hydrocarbon liquid of viscosity greater than gasoil containing 0.5 to 5 percent of chemically combined sulfur in a reactive condition and also containing 0.5 to 2 percent of a compound of a metal group e.g., tin or lead, which is capable of reacting with the sulfur compound to give increased lubricity. (K 38)
12. N. V. de Bat. Petr. Maat., French Patent 764,721 (December 1, 1933); Chem. Zentr. pt. II, 2157 (1934). A small amount of nitrogen sulfide, N_4S_4, is added to fuels for diesel engines.
13. Phosphorus sesquisulfide (See C 15).
14. Paulsen, H. C., and Collins, J. O., (Standard Oil Development Company), U. S. Patent 2,280,716 (April 21, 1942); C. A. 36, 5637[3] (1942). A hydrocarbon diesel fuel oil has mixed with it about 0.1-5 percent of N tetrasulfide, serving to facilitate ignition, and with about 0.001-0.005 percent of 1-mercaptobenzothiazole, to inhibit deterioration of the N tetrasulfide.
15. Ethyl disulfide (See K 60).
16. Benzylsulfides, diphenyl sulfide (See C 19).
17. Carbon disulfide (See B 46).
18. Seeley, C. H., and Arveson, M. H., (Standard Oil Company [Indiana]), U. S. Patent 2,205,126 (June 18, 1940). Alkyl polysulfides prepared and dissolved in a hydrocarbon solvent for use as an ignition accelerator.
19. Standard Oil Development Company, British Patent 544,492 (April 15, 1942). A fuel from compression-ignition engines comprising a diesel fuel oil containing from 0.1-0.5 percent of nitrogen tetrasulfide and 0.001 percent of 2-mercaptobenzothiazole.
20. Standard Oil Development Company, British Patent 546,780 (July 30, 1942). A solid or partially solid promoter is added to the diesel fuel to increase the cetane number. The addition comprises an alkoxy phosphopolysulfide, a mercaptobenzothiazole, an acylamine or oxime, a thiocarbazone, a thiocarbamate or a sulfurized derivative thereof. (K 77)
21. Taveau, R. de M., (The Texas Company), U. S. Patent 2,034,643 (March 17, 1936). Compression ignition is aided and accelerated by the addition of a small amount (0.5 to 5 percent) of polysulfide of the general formula R-S-S-S-S-R where R may be any alkyl or aryl radical or substituted alkyl or aryl group. Diethyl tetrasulfide is given as an example. 1 percent of which in a gasoil increased the heptane number from 64 to 85. Di-p-tolyl tetrasulfide increased the heptane number to 76.
22. Organic polysulfides (See D 86).

K. Unclassified

1. Badertscher, O. E., and Altamura, M. S., U. S. Patent 2,218,447 (October 15, 1940). To decrease the ignition delay period, a diesel fuel oil has mixed with it an aliphatic S-containing amine.
2. Barnard, D. P., IV, U. S. Patent 2,125,875 (August 9, 1938). Use of paraffin wax and a pour-point depressor for increasing cetane number.
3. Behm, H., U. S. Patent 1,813,382 (July 7, 1931). Slaked lime, rosin, formaldehyde, ammonia, turpentine followed by contact with air to improve ignition quality of diesel fuels. (B 2)
4. Elementary sulfur (See J 1).
5. Boerlage, G. D., J. Pet. Tech. 22, 455-68 (1936). Correlation tests on the ignition quality of diesel fuels. (Vegetable oils and doped fuels.)
6. Bristow, W. A., and Buist, C., British Patent 461,320 (February 10, 1937). Treating high-boiling oils such as coal oil or other liquid fuel for use in compression-ignition engines of the diesel type by the addition of a primer in the proportion of 0.5 to 5 percent to lower the spontaneous-ignition temperature of the high-boiling oil or to reduce the delay period between injection and ignition of the fuel, the primer being either nitroxyl-ethylene-chlorhydrin or nitroxyl-ethylenebromhydrin. Also Indian Patent 23,109 (1937).
7. Burton, A. A. (Standard Oil Company of California), U. S. Patent 2,200,260 (May 14, 1940). Trichloronitromethane, otherwise known as chloropicrin, is used as a diesel dope. Claim is made that it tends to help cold starting by lowering the cold-starting temperature by 1° F. cetane number increase, and also tends to eliminate combustion-chamber deposits. (D 10, E 4)
8. Butler, W. H., Diesel Fuel Power, 9, 456-9 (1931). High-speed diesel fuels, Catalysts for the ignition of oils. Distillation curves for diesel oils.
9. Carini, C., Italian Patent 290,137 (May 28, 1930); Chem. Zentr. pt. I, 1346 (1937). Increasing the combustion of hydrocarbon oils by adding 1-3 percent of a mixture of diazo and nitro compounds, or hydrazo and polynitro compounds.
10. Chlorine compounds (See D 12, D 13).
11. Sulfur (See J 4).
12. Classen, M. H. K., German Patent 611,968 (April 10, 1935). Colloidal active carbon with furfurol as a diesel dope.
13. Phenylhydrazine or derivatives (See D 15).
14. Conquest, V. (Armour & Company), U. S. Patent 2,135,327 (November 1, 1938). Motor fuel containing nitriles. Gasoline or kerosine and straight-chain aliphatic nitrile of at least 12-carbon atoms.
15. Crandall, G. S. (Socony-Vacuum Oil Company), U. S. Patent 2,188,262 (January 23, 1940). Relates to the use of the pentazadienes as diesel dopes. These materials show an effectiveness approximately 75 percent that of ethyl nitrate. Difficult synthesis and probable instability make their usefulness doubtful.
16. Crandall, G. S., Moran, R. C., and Berger, H. G., (Socony-Vacuum Oil Company), U. S. Patent 2,167,345 (July 25, 1939); C. A. 33, 8962 (1939). A small proportion (about 0.4 percent) of a mercaptan such as isoamyl mercaptan is dissolved in a mineral hydrocarbin fuel, and the fuel is then sweetened in the presence of S, resulting in a decrease in the ignition-delay period of the fuel.
17. Deuthche Pyrotech. Fabr., German Patent 502,757 (August 5, 1930). Process for igniting different ignition reaction mixtures, especially for internal-combustion engines. Highly compressed mixtures of amonium nitrate and carbon, an ignitor of barium nitrate, aluminum, sulfur and flour is spread in a thin layer. (C 3)
18. Edeleanu Gesellschaft m.b.H., British Patent 381,941 (October 10, 1932). Favorable results are obtained by adding to a diesel oil which ignites badly, a relatively small quantity, not substantially exceeding 30 percent of the sulfur dioxide raffinates obtained by the treatment of a gasoil or diesel oil by the known Edeleanu process. The same effect can be obtained if the diesel oil is subject to a partial extraction with sulfur dioxide, sufficient to remove only up to 75 percent of the quantities that could be extracted from the oil. In this way good motor oils with low ignition are obtained and there is also the advantage of using considerably less sulfur dioxide and having less extraction than in the hitherto known extraction of gasoils, where the object has been to remove the aromatic constituents as completely as possible. German Patent 573,211 (March 29, 1933). French Patent 718,688 (1931).
19. Fuller, E. W., and Nygaard, E. M., (Socony-Vacuum Oil Company), U. S. Patent 2,314,137 (March 16, 1943). Ignition accelerator for diesel fuels comprising an alkyl-, cycloalkyl-, aralkyl hy-

3 **EXCLUSIVE CHEMICAL ENGINEERING DATA** continuously compiled over the years by The M. W. Kellogg Company proved its full value in the successful development of Cities' project. Based on this data and Kellogg's development of *Fluid* catalytic-cracking . . . the "Cat-Crackers" in this refinery were designed *before* a single such Fluid unit was in operation!

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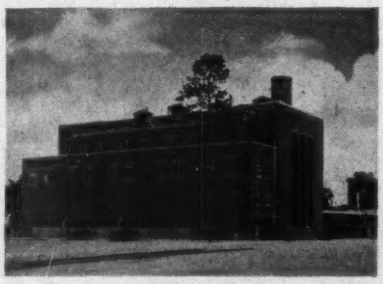
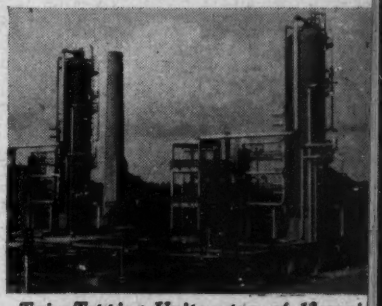
Intricate piping specifications were accurately established by exclusive stress measuring device.

5 **CONSTRUCTION-WISE,** more refining records were set. Better than 25,000,000 man-hours were expended and at peak of the work, M. W. Kellogg's permanent construction crew supervised 11,000 workmen on the job. Working against time and the infinite complications brought about by the war . . . the crew built and linked *thirteen* different major refining units — requiring 250 miles of continuous welding; 1,100 miles of pipe and tubing; a power plant big enough to supply a city of 250,000 people with electricity!



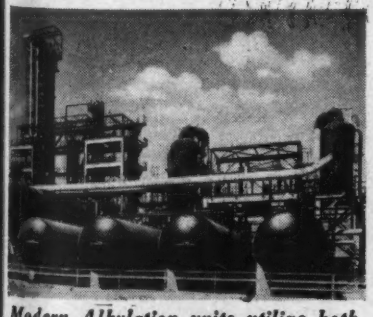
Power house, railroad spurs, docking facilities are but a few of the supplementary projects completed.

6 **ANOTHER REASON** why Kellogg-completed plants operate as designed can be found in the work done by the Kellogg initial operations staff on the Cities' project. These men, with broad experience in all phases of modern refining, assisted the refinery's permanent staff to start up each unit as it was completed. And each unit operates successfully *—as specified.*



Twin Topping Units—two of 13 major units to be put on stream.

7 **THE ALL-IMPORTANT PROTECTION** of the client's interests in the process rights is always part and parcel of M. W. Kellogg operations. Licenses for all major refining processes embodied in the Lake Charles refinery were arranged by Kellogg.



Modern Alkylation units utilize both butenes and pentenes.

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droxylamine, e.g., dicyclohexyl hydroxylamine.

20. Halogen (See D 25).
21. George, R. S., Crandall, G. S., Nygaard, E. M., and Badertscher, D. E., U. S. Patent 2,266,021 (December 16, 1941); J. Inst. Petroleum 28, 374 (1942). Addition to diesel fuel of a compound having the general formula R.CX.SNO in which R represents a radical selected from the group consisting of alkyl, alkaryl, aryl, and aralkyl radicals, and X is selected from the group consisting of oxygen and sulfur. The compound is added in sufficient quantity to decrease the ignition-delay period.
22. Sulfur compound (See D 22).
23. Hartner-Seberich, R. Brenn.-Chem. 14, 141-7 (1933). Reducing the auto-ignition of coal-tar oils. Refers to the difficulty of using the oils for diesel motors, owing to their high ignition temperatures, difficult combustion and low lubricating value. Gives method of determining self-ignition temperature and a table of these values for 40 different 10-percent mixtures including: aldehydes, vegetable oils, iron pentacarbonyl, amyl nitrate, furfurol, olive oil, nitrotoluene, glycol, monoethanolamine, diethanolamine, triethanolamine, nitroaniline, dinitrobenzene, diesel oil, paraffin oil, turpentine oil, etc. (B 23, D 26, E 11)
24. Ethylenochlorohydrin nitrate (See D 27).
25. Halogen nitrates (See D 29).
26. Benzyl bromide (See D 39).
27. Hulse, S. H., and Collins, J. O., (Standard Oil Development Company), U. S. Patent 2,288,401 (June 30, 1942); C. A. 37, 5255 (1943). A method is employed for improving sour diesel fuel petroleum distillates which comprises adding to a sour petroleum diesel fuel, distillate oil containing at least 10 mg. of mercaptan S per 100 ml. of the oil, PbS, an alkali and reactive S, the reactive S being added in a proportion to form by reaction with the mercaptans stabilized organic compounds containing from 20 to about 200 mg. of active S per 100 ml. of the oil, and treating the mercaptans with the reactive S in the presence of PbS substantially all combined Pb persisting as a catalyst throughout the reaction to form stabilized organic S compounds which satisfactorily permit the product to pass the A.S.T.M. copper-strip corrosion test.
28. Organic bromine compounds, e.g., benzyl bromide, cyclohexylbromide, butyl bromide (See D 41).
29. Bromine compounds, e.g., benzyl or butyl bromide (See D 45).
30. I. G. Farbenindustrie, French Patent 828,861 (June 1, 1938); C. A. 33, 1124 (1939). Diesel oils are improved by adding a small amount of highly polymerized hydrocarbons, the mol. weight of which is of the same order as that of natural or artificial rubber. Thus, crude natural rubber 0.25, or a polymerization product of isobutylene (mol. wt. 200,000) 0.1 percent may be used.
31. Chlorine compounds (See A 8).
32. Joachim, W. F., "U. S. Navy Correlation of Laboratory Tests on Diesel Fuels with Service Engine Operation." Oil and Gas Power Division, A.S.M.E., State College, Pa. (August 18-21, 1937). Refers to service and laboratory experiments with a large number of doped fuel oils.
33. Halogen (See D 47).
34. Leroy, M., French Patent 710,496 (January 21, 1931); C. A. 26, 1756 (1932). Liquid motor fuels are improved by the introduction of graphite, particularly in the colloidal state, with or without a support such as a mineral oil of 0.9 density or "limon."
35. Lieber, E., and Miller, P., U. S. Patent 2,214,059 (September 10, 1940); J. Inst. Petr. 493A (1940). Fuel for diesel engines consisting essentially of a hydrocarbon fuel with which is blended a minor proportion of a tertiary alkyl nitrosyl mercaptan.
36. Lorang, H. F. J., French Patent 755,820 (November 30, 1933); C. A. 28, 2174, (1934). Addition of methyl anthranilate, acridine, aniline, furfurol, naphthol, quinoline, nitrobenzene, glycol nitrate, ammonium nitrate, amyl nitrate, acetylene, etc., to kerosine. (A 10, D 49, E 18).
37. Lubovitch, E., British Patent 403,770 (January 4, 1934). Liquid fuel. Combustion improved by the addition of oxides or salts of the rare earths to the fuel.
38. Sulfur compounds (See J 11).
39. Menz, H., Steffen, W., and Jaaks-Muncheberg, E., British Patent 331,966 (April 30, 1929). Tetralin, sulfonated castor oil, water containing sulfite lye as diesel fuel ignition accelerators.
40. Meyer, E. G., British Patent 269,222 (December 3, 1925); B.C.A.-B. 721 (1927). There are added to liquid hydrocarbons of relatively high boiling point, small quantities of volatile basic substances such as ammonia and ether. (B 32)
41. Meyer, E. G., British Patent 411,904 (December 15, 1932); B.C.A.-B. 749 (1934). Up to 1 percent of ether, acetone, and ammonia are added to diesel fuel. (B 33)
42. Michel, C., French Patent 787,222 (September 19, 1935); C. A. 30, 1212 (1933). Radioactive materials are added to hydrocarbon oils to cause ionization or vaporization.
43. Miller, P., and Lieber, E. (Standard Oil Development Company), U. S. Patent 2,310,306 (February 9, 1943). A solid and at least partially soluble ignition promoter is added to diesel fuel to increase the cetane number. Additions may consist of crushed or powdered sulfur, S_4N_4, alkoxyphospho polysulfides, heterocyclic compounds such as mercaptobenzolthiazole, acyl amines, acyl oximes, sulfurized aliphatic amines, alkyl hydrazones or corresponding alkylaryl derivatives, nitro urea, thiocarbazones, thiocarbamates, and sulfurized derivatives.
44. Miller, P., and Cloud, G. H., (Standard Oil Development Company), U. S. Patent 2,316,011 (April 6, 1943). A compression-ignition fuel comprising a hydrocarbon diesel fuel oil and 0.2 to 3 percent of 1-butylmercaptobenzothiazole.
45. Moness, E., J. Am. Ph. Assoc. 25, 397-402 (1936); C. A. 30, 5198 (1936). Persulfide preparation.
46. Moore, C. S., and Foster, H. N., N.A.C.A. Technical Note No. 707 (1939). "Compression Ignition Engine Performance with Undoped and Doped Fuel Oils and Alcohol Mixtures." (B 36)
47. Moran, R. C., Fuller, E. W., and Crandall, G. S., (Socony-Vacuum Oil Company), U. S. Patent 2,136,455 (November 15, 1938). The improvement of a diesel fuel is effected by shortening the delay period by the addition of 0.5 to 3 percent of diazoaminobenzene.
48. Moran, R. C., Fuller, E. W., and Crandall, G. S., (Socony-Vacuum Oil Company), U. S. Patent 2,136,456 (November 15, 1938). The quality of a diesel fuel is improved by the addition of small quantities (0.5-3 percent) of a substituted triazene of the general formula R′ R′ N—N=N—R, in which R, R′ and R′′ represent hydrocarbon radicals or substituted hydrocarbon radicals in which R′ or R′′ may be replaced with hydrogen or may represent the hydrocarbon portion of a heterocyclic compound containing a nitrogen atom, as for example in the piperidide compounds. Examples given are phenyl diamyltriazene, ethyldiphenyl triazene, diphenyl triazene, etc.
49. Moran, R. C., and Badertscher, D. E., U. S. Patent 2,115,275 (April 26, 1938). An improved diesel fuel, comprising a liquid hydrocarbon fuel and in admixture therewith a minor proportion, sufficient to decrease the ignition-delay period of the fuel, of one or more compounds, selected from the group consisting of triazo acetone, triazo ethanol, ethyl triazo formate, triazoethyl triazoacetate, and 1:2 diazido ethane.
50. Moran, R. C., and Crandall, G. S., U. S. Patent 2,137,410 (November 22, 1938). An improved diesel fuel comprising: a hydrocarbon oil and in admixture therewith a minor proportion of sulfurized terpene, pine oil, a material that is predominantly terpene, in an amount sufficient to decrease the ignition-delay period of the fuel.
51. Nitrogen sulfide (See I 25).
52. Mortenfabrik Deutz A. G., British Patent 289,400 (June 20, 1928), Chem. Zentr, pt. II, 514 (1938). Ignition composition for starting internal combustion engine. Ignition mixture formed from potassium chlorate, sulfur, and carbon. (C 16)
53. Murphy, G. B., and Hubner, W. H., U. S. Patent 2,203,838 (June 11, 1940). Use of chlorine as a diesel dope. Chlorine is shown to have an effect equivalent to that of ethyl nitrate when added to the same base stock.
54. Nash, A. W., and Howes, D. A., "The Principles of Motor Fuel Preparation and Application," Chapman & Hall, London, 1935, Vol. II, 460-464. General discussion of diesel combustion accelerators.
55. Nygaard, E. M., McCracken, J. H. and Seger, F. M., (Socony-Vacuum Oil Company), U. S. Patent 2,326,102 (August 3, 1943); C. A. 38, 469 (1944). For improving its ignition properties, a hydrocarbon diesel fuel has mixed with it about 0.1-5 percent of the oil-miscible product obtained by first treating perchloromethyl mercaptan with phenol, methyl mercaptan or similar compounds.
56. Chlorates and sulfur (See H 19).
57. Sulfur (See D 59).
58. Chloroethyl nitrate (See D 64).
59. Amines (See C 20).
60. Porter, H. R., SAE Journal 51, 356 (1943). "Cold-Starting Tests on Diesel Engines." Chlorine, hydrogen sulfide, amyl nitrate, ethyl disulfide, trichloronitromethane, etc., are effective in aiding starting when added to the intake air. (D 62, E 30, J 15).
61. Pyzel, D., (Shell Development Company), Canadian Patent 346,022 (November 13, 1934). The use of sulfur dioxide raffinate to improve combustion quality of diesel fuels.
62. Rabetrano, E., French Patent 802,259 (September 1, 1936); C. A. 31, 1588 (1937). Improving the combustion of oils, benzines, benzol, fuel oils, gas oils, masut, etc. A small amount of amines, amides, or oxycompounds of naphthalene are added; lubricants may be added also. Products of naphthalene having amine, amide, or hydroxyl functions.
63. Seger, F. M., and Nygaard, E. M., (Socony-Vacuum Oil Company), U. S. Patent 2,329,489 (September 14, 1943). An improved diesel fuel comprising a hydrocarbon fuel oil and in admixture therewith, a minor proportion of the non-volatile oil-soluble product obtained by reacting perchloromethyl-mercaptan with elementary sulfur, said non-volatile reaction product containing only carbon in chemical combination with substantial proportions of chlorine and sulfur.
64. Shen, G., Wood, C. E., and Garner, F. H., Oel & Kohle, 15, No. 24, 435 (1939). Evaluation of m-alkylated benzenes as diesel motor fuels; n-nonylbenzene is suitable.
65. Shoemaker, B. H., and Loane, C. M., (Standard Oil Company [Indiana]), U. S. Patent 2,169,186 (August 8, 1939). Diesel fuel. A high-speed diesel fuel. Fuel oil and an organic compound of the formula a-RSNX_m; R = alkyl or aryl radical; X = an element of the group-oxygen and sulfur; m = whole number not greater than 2.
66. Shoemaker, B. H., and Batchelder, H. R., (Standard Oil Company [Indiana]), U. S. Patent 2,184,440 (December 26, 1939). The use of sweetened isoamyl mercaptan to improve the ignition of diesel fuel.
67. Shoemaker, B. H. (Standard Oil Company [Indiana]), U. S. Patent 2,230,817 February 4, 1941). Similar to K 72.
68. Chlorine compounds, amines, halogen, and azo compounds (See D 70).
69. Azo compounds (See F 5).
70. Dichlorethylene, powdered coal, coke, lime, coal, oil, soda, water, and ammonia chloride (See B 48).
71. Southcombe, J. E. (Germ Lubricants, Ltd.), British Patent 396,427 (August 2, 1933); B.C.A.-B. 853 (October 27, 1933). To a light diesel fuel oil is added > 2 percent (preferably 1 percent) of an organic acid of high mol. wt. (e.g., oleic acid or a mixture thereof with lubricating oil).
72. Standard Oil Company (Indiana), French Patent 830,882 (1938). In the treatment of sour distillates with plumbite for the production of diesel fuels, a large excess of sulfur is used, which is claimed to improve the ignition tendency of the fuel.
73. Standard Oil Development Company, British Patent 521,786 (May 30, 1940); J. Inst. Petroleum 379A (1940). Fuel for compression-ignition engines of the diesel type consisting of a hydrocarbon fuel and a small amount of an organic compound containing in the same molecule a diazo group and a carboxyl group to impart better ignition qualities to the fuel.
74. Standard Oil Development Company, British Patent 533,645 (1942). A diesel fuel containing from 0.1 to 5 percent of a compound of the formula (RS) 3PX, where X is O or S, specifically; triphenyl tetrathiophosphate, triamyl trithiophosphate, etc.
75. Amines (See D 73).
76. Thionitrites, sulphonylhydroxylamines, etc. (See D 74).
77. Amines, sulfur derivatives (See J 20).
78. Standard Oil Development Company, British Patent 544,417 (April 13, 1942). A compression-ignition fuel containing 0.2-3 percent of an organic compound containing a 5-membered heterocyclic ring containing N and S, such as: 2-methyl benzothiazole, benzothiazoyl hydrazine, primuline base, etc.
79. Standard Oil Development Company, British Patent 432,592 (March 21, 1934). Liquid fuels for diesel engines, etc. Hydrocarbone liquids boiling in or above the kerosine range and 0.1 to 5.0 percent of true esters boiling above 302° F. and containing carbon, hydrogen, and oxygen. Esters are described in British Patent 403,262 (1932) or amyl stearate, butyl acetyl ricinoleate or benzyl or hexyl esters of wax-oxidation acids. Fuel described in British Patent 378,089 (1932) may be used. Organic acids, fatty or naphthenic acids, active halogen compounds (carbon tetrachloride, benzyl chloride, and chlor-fatty acids or mineral oils), active sulfur compounds such as sulfurized vegetable oils or mineral oils, or paraffin wax, lead or tin compounds, load carrying agents such as de-flocculated graphite, nitro compounds; knock reducers such as ethyl nitrate or peroxides, dyes; in-

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hibitors, or gum fluxes such as naphthenic oil may be added. (B 50, C 25, D 76, E 36, I 45).

80. Standard Oil Development Company, British Patent 523,143 (July 5, 1940); C.A. 35, 6093[1] (1941). Organic compound containing a thiocarboxylic acid radical for use as a diesel fuel ignition accelerator.
81. Halogens, sulfur compounds (See B 49).
82. Standard Oil Development Company, French Patent 853,052 (March 9, 1940); C.A. 36, 2392[7] (1942). A diesel fuel composed of combustible hydrocarbons and a small quantity of an organic compound containing a —SNO, —SNO_2 or SNOH group linked to a C atom.
83. Ammonia, sulfur, turpentine (See B 51).
84. Stillman, A. L., British Patent 497,786 (December 28, 1938). Fuel oils. Ignition point is reduced by mixing oil with ½ percent of "waste gypsum," obtained from the acid treatment of phosphate rock. Addition as colloid or suspension. Trisodium phosphate may be added.
85. Aromatic amines (See B 53).
86. Aniline, toluidine (B 54).

INDEX LITERATURE AND PATENT SEARCH

Ignition Accelerators for Compression-Ignition Engine Fuels

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Literature and Patent Search

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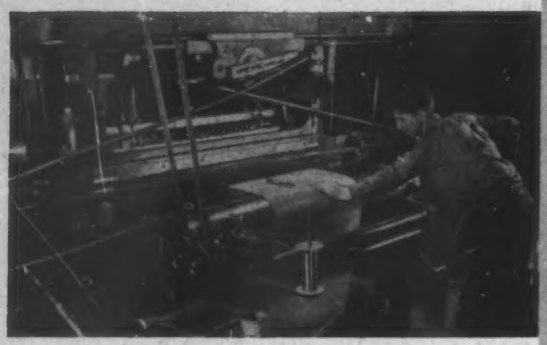

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Higher fatty acids: H25
Oxidation, general: A8, B22, B49, H9, H14, H16, H25, H28
Oxygen: E26, H2, H4, H5, H8, H10, H13, H18, H19, H21, H23, H26, H27
Ozone, ozonides: E26, H1, H3, H12, H15, H17, H20, H22

I. Peroxides
Acetone peroxide: I5, I11, I23, I25, I26, I27, I30, I31, I32, I41, I45
Aldehyde peroxides: I23, I26, I27, I49
Alkyl peroxides: B4, D31, D32, D33, I4, I9, I10, I35, I44
Alkylidiene peroxides: I39
Aromatic peroxides: D15, D31, D32, I6, I12, I34, I41
Benzoyl peroxides: D31, D32, D33, I6, I12
Diacyl peroxide: I44
Diacetyl peroxide: I4, I35
Diethyl peroxide: I9
Dipropionyl peroxide: I35
Ethyl peroxide: I10
General: D15, D29, D34, D59, D70, H8, I1, I6, I8, I9, I29, I34, I39, I40, I42, K79
Hydrogen peroxide: D52, I6, I10, I20, I41, I42
Ketone peroxides: B4, D5, I5, I11, I12, I23, I24, I25, I26, I27, I28, I30, I31, I32, I37, I39, I41, I46 I47 I48, I49
Lauroyl peroxides: I19, I44
Peroxides of anhydrides from fatty acids: D3
Sodium peroxide: I36
Tetralinperoxide: D27, D28, I11, I18, I22, I25, I29, I32, I38, I39

J. Polysulfides
Alkyl polysulfides: J5, J18
Aminoaryl disulfide: J6
Benzyl sulfide: C19
Carbon disulfide: B46
Diamylamine disulfide: J10
Diethyl tetrasulfide: D27, J21
Diphenyl sulfide: C19
Ethyl disulfide: K60
Hydrogen persulfides: J1
Nitrogen sulfides: I11, J12, J14
Phosphorous sesquisulfide: C17, J2
Polysulfides, general: C17, D15, D29, D86, J4, J11, J19, J20, J21
Sulfocarboxylethyl disulfide: J4

K. Unclassified
Amines: B53, B54, C20, D70, D73, D74, J20, K23, K36, K47, K62
Ammonia: A4, B51, F3, K3, K40, K41
Azo compounds: B38, B39, D70, E35, F5, K9, K47, K49, K73
Benzenes: A2, A9, A14, B51, E8, E17, K64
Benzyl bromide: D39, D41, D45
Butyl bromide: D41, D45
Chlorates: H19
Chlorine: K53, K60, K63
Chlorine compounds: A8, B48, B49, D12, D13, D64, D70, K79
Chloropicrin: D12, D59, K7, K60
Colloidal active carbon: K12, K34
General: K5, K8, K32, K46, K54, K84
Halogens: B49, D25, D29, D39, D41, D47, D70, K79
Halohydrins: D27, K6
Hydrazines: D15
Hydroxylamines: K19
Mercaptans: K16, K27, K35, K55, K63, K66
Nitriles: K14
Organic materials, general: A8, B48, D59, K30, K71, K79
Paraffin wax: A8, K2
Pentazadienes: K15
Radioactivematerials: K42
Salts of the rare earths: K37
Sulfur, elementary: D59, H19, J1, J4, K16, K17, K27, K43, K52, K63, K67, K72
Sulfur, general: B49, D59, I25, J11, J20, K21, K36, K43, K44, K45, K65, K74, K78, K79, K80, K82
Sulfur-containing amines: K1
Sulfur-dioxide raffinate: K18, K61
Sulfonated castor oil: K39
Sulfurized terpene: K50
Thiocarboxylic acid radical compounds: K43
Thionitrates and thionitrites: D22, D74
Triazenes: K48
Turpentine: B51, D44, K3, K23

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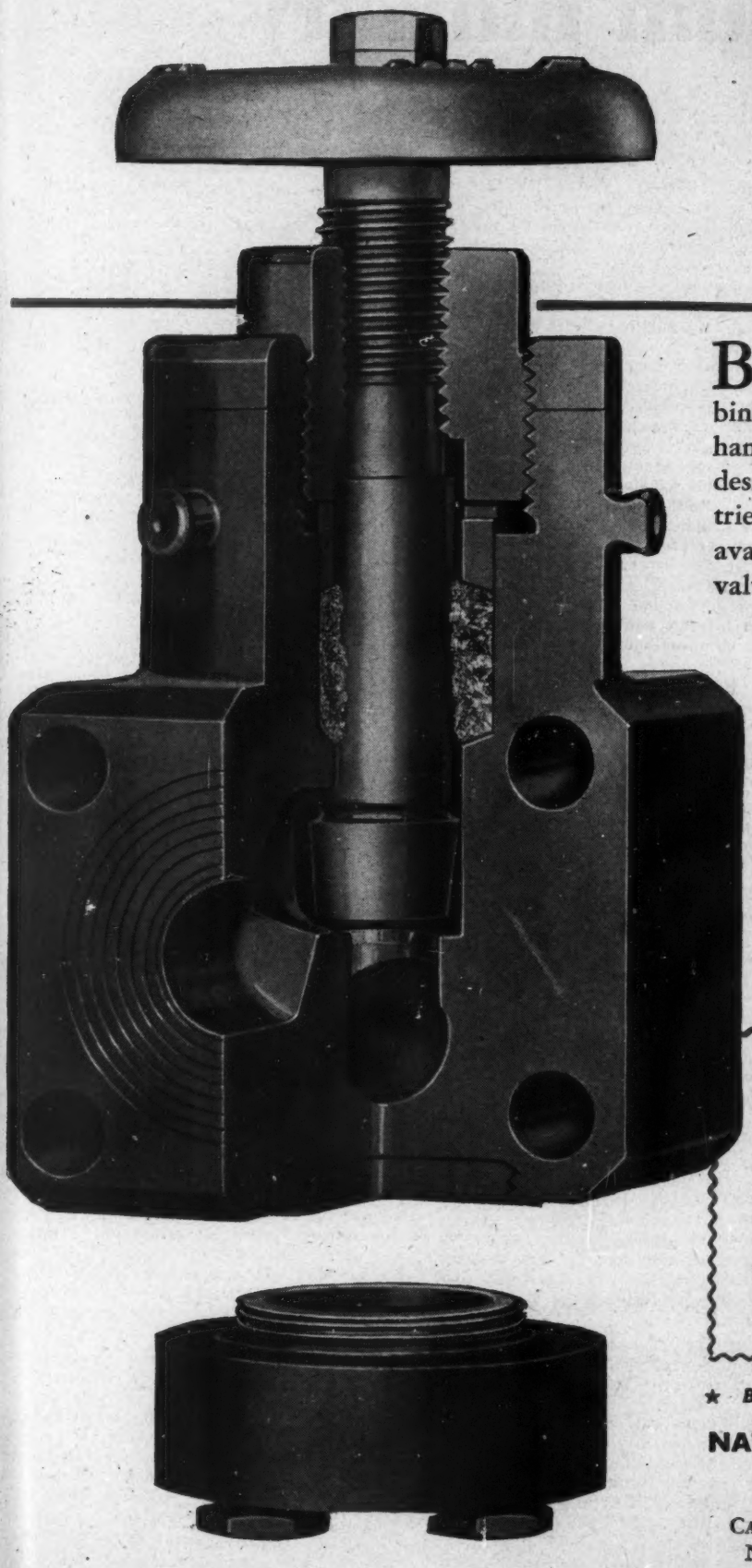

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Co-operative Movement Hits Petroleum Industry

WITH formation of the National Co-operative Refinery Association in July of 1943 by five large regional cooperative associations for the purpose of purchasing the Globe Oil Refinery, located at McPherson, Kansas, and announcement of the proposed organization of an International Cooperative Trading and Manufacturing Association to engage in all phases of petroleum, co-operators served notice on the petroleum industry that by utilizing war-swollen, tax-free profits and the many special privileges accorded them by government, they seek to monopolize international business and to ultimately replace the present profit system.

The plan for world cooperative dominance has been well described in the fifteenth annual report of Consumers Cooperative Association, of North Kansas City, Missouri, which reads as follows:

> "The consumer cooperative movement in the United States is beginning to emerge as a national movement . . . regional cooperative wholesales have joined hands on a national basis in petroleum . . . there will be examples of such teamwork in other fields . . . then to unite with cooperatives internationally in production and distribution will be a next and relatively easy step . . . it is a step that must be taken if the common people we represent are to provide checks and balances against the grand-scale monopolies at home and the super cartels abroad."

There can be no doubt that great progress has been made in bringing the plan to actual accomplishment. The framework has been completed. Expansion of present cooperative activities will bring it to a conclusion.

Cooperative Activities Numerous

Today, 2327 local cooperative associations supply more than 20 percent of petroleum fuels used on American farms and are making substantial inroads on the urban market. They serve more than 600,000 members and do an annual business in excess of $197,000,000. Regional co-ops own and operate 11 refineries, and are planning the purchase of additional refining facilities. They are also conducting exploratory operations and are engaged in crude production. One regional cooperative wholesale alone owns 289 oil wells and 867 miles of pipe line. Their facilities are further implemented by the ownership and operation of river terminals, barge lines, and oil compounding and blending plants.

Reasons for Success

Petroleum and other cooperatives have prospered as a result of the many special privileges and favors granted by government. These have given them many unfair competitive advantages over private business. They enjoy cheap and favorable government credit. Their growth has been promoted by government. They have been exempt from business regulatory laws. They pay very little or no federal income and excess profits taxes.

In order to maintain their freedom from federal income and excess profits taxes, cooperatives must distribute their profits to the patrons on a basis of their purchases, and are not allowed to accumulate unreasonable reserves. They have, however, devised many means for circumventing the law in this respect, and have been able to retain their profits, in many instances, for use of the association.

Because dollars saved through tax exemption represent much of the investment in new facilities of cooperative enterprise, it is reasonable to conclude that cooperative ownership is indirectly paid for by all taxpayers, and that the individual cooperative members who profit thereby are being unduly enriched at the public's expense. An illustration of this effect is provided by the record of 14 major cooperatives, which had combined earnings of $10,383,177 during their fiscal years ending in 1942. They would have paid approximately $6,582,943 in federal income and excess profits taxes if they had been taxed at the average rate paid by private industry (63.4 percent.) Instead this and additional funds, amounting to $7,285,073, were retained in the capital structure and, therefore, were available for expansion. The rest of the non-taxed net earnings, $3,098,104, were returned to the patrons in the form of cash dividends and stock.

A PRELIMINARY report on the expansion of the cooperatives in the petroleum industry has been issued by the Research Department of the National Tax Equality Association.

Telling of the creation and operation of super-cooperatives in this industry, their financing, their purchases of refineries, pipe lines, and producing fields, and the growing volume of their business, the report concludes that the great expansion of these businesses has resulted from their exemption from Federal income and excess profits taxation and other privileges granted by Government.

"With some semblance of competitive equality," says the report, "the petroleum industry could offer little objection to the competition of cooperatives and should be able to compete successfully. It cannot, however, pay its share of the high cost of war and at the same time, through taxation and many other competitive disadvantages, support its opposition."

The accompanying condensation of the preliminary report has been released by the National Tax Equality Association with the request to the oil industry that the facts and figures be examined closely, and that any comments, criticisms and additions to the factual data be supplied by all branches of the industry before the final report goes to press.

Future Objectives

As previously pointed out, the leaders of the cooperative movement have indicated that their consumer market will ultimately embrace the entire world in the field of petroleum distribution. At the present time they are actively engaged in extending their distribution into urban areas. To supply this ever increasing market of petroleum products will require additional production and refining facilities. There can be little hope that petroleum cooperatives will discontinue their absorption of oil fields, refineries and pipe lines until they have sufficient capacity to service the entire demands of their consumer market. This fact was well established when the five major petroleum wholesales pooled their interests to purchase the Globe Refinery. At that time the leaders of the movement declared, "Cooperative wholesales, being service organizations, are seeking, through the purchase of additional refining facilities, to meet the refined fuel needs of their members 100 percent."

Formation of World Oil Cartel

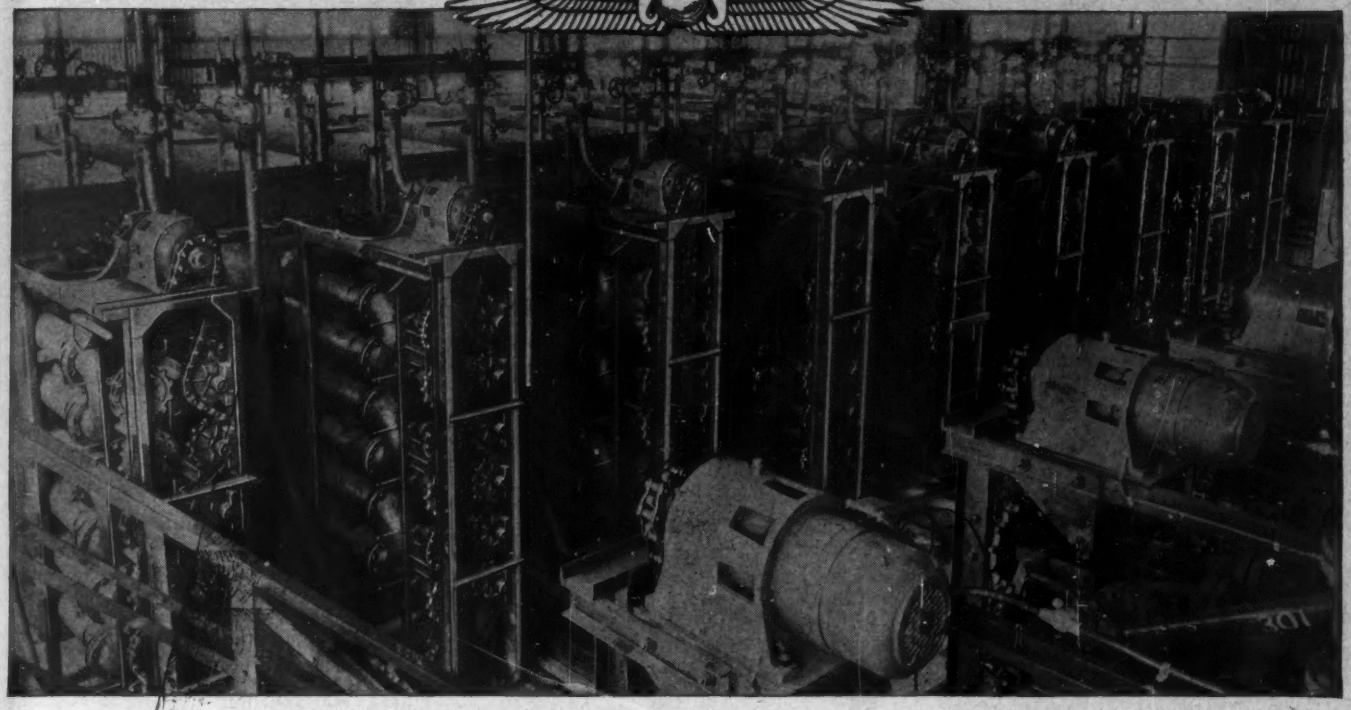
On January 17, 1944, directors of the Cooperative League meeting in Washington, D. C., voted unanimously to organize the International Cooperative Trading and Manufacturing Association—"to engage in all phases of the petroleum industry and in food distribution." The plan was presented by Howard A. Cowden, vice president of the League and chairman of its committee on international cooperative reconstruction.

The plan was later presented to representatives from 22 countries, attending a conference on cooperative rehabilitation. It was approved by this group in principle and later will be presented to cooperative organizations all over the world for ratification.

This would not be an entirely new undertaking, since the Consumers Cooperative Association, headed by Cowden, shipped significant quantities of grease and oil to cooperatives in Canada, Scotland, Sweden, Holland, France, Esthonia, Finland and Bulgaria prior to the war. In exchange, they received large shipments of tea.

Capital requirements of this huge undertaking were estimated at $12,160,000 as a maxmium figure to begin petroleum distribution on an interna-

LET'S FOLLOW THE REFRIGERANT THROUGH A WORTHINGTON DOUBLE-PIPE CHILLING MACHINE



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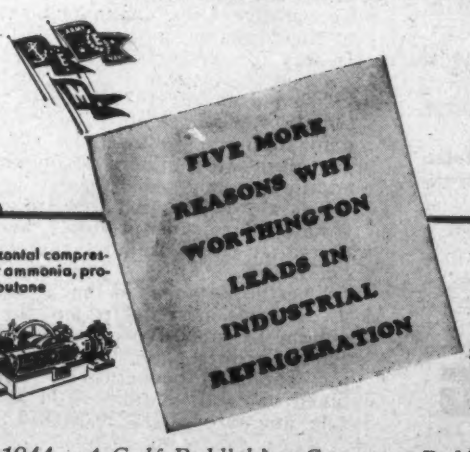
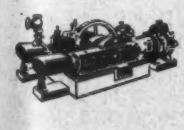


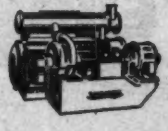
BEHIND THE NAME WORTHINGTON

1. Horizontal compressors for ammonia, propane, butane

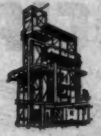


2. Angle engine compressors

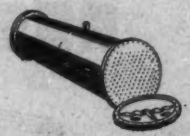
3. Centrifugal compressors

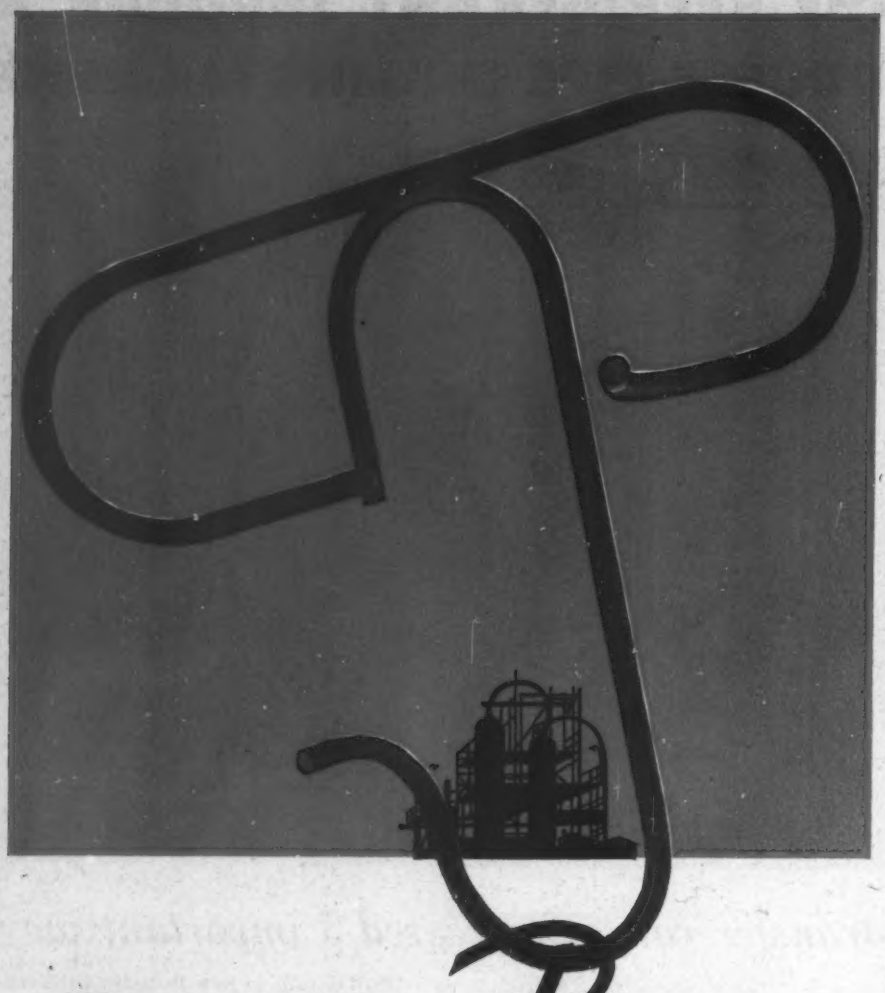


4. Absorption refrigerating machines



5. Shell and tube refrigerating equipment





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tional scale. It was suggested that 80 percent of the cost be borne by overseas cooperatives and 20 percent by cooperatives in the United States. It has been indicated that a portion of the money might be obtained from PRC.

The large regional wholesale petroleum cooperatives pooled their interests to form a "super petroleum cooperative" to purchase the Globe Refinery at McPherson, Kansas. The purchase of this refinery was of particular significance to the petroleum industry, since it represented the first national federation of cooperatives to enter the fields of petroleum production and refinery operation. The National Cooperative Refinery Association was created by Central Cooperative Wholesale, Superior, Wisconsin; Midland Cooperative Wholesale, Minneapolis, Minnesota; Farmers Union Central Exchange, St. Paul, Minnesota; Farmers Union State Exchange, Omaha, Nebraska; and Consumers Cooperative Association, North Kansas City, Missouri.

The Globe Refinery was built in 1932 as a 7500-barrel plant. It had been enlarged from time to time and, when purchased by the regional cooperatives, had an extreme capacity of 17,500 barrels of crude per day. The purchase included a 6-inch, 229 mile pipe line from McPherson to Council Bluffs, Iowa, together with land, buildings, storage tanks, and equipment.

The association was incorporated with an authorized capital of $2,010,000, or approximately 40 percent of the cost of $5,000,000. The five wholesale associations participating in the purchase subscribed to stock of NCRA in the amount of $1,550,000. It is probable that the remainder of funds for the refinery purchase was financed by a loan granted by the Wichita Bank for the Cooperatives. These loans bear interest at the rate of 3½ percent, are secured by first mortgage on the property, and may be made in an amount up to 60 percent of the appraised value of the facilities acquired.

Engaged in Refining and Producing

The super petroleum cooperative, of course, was preceded by many large regional cooperative wholesales. These wholesale associations were originally organized by the local cooperative associations to capture the economies resulting from large-scale purchases. At first they were little more than brokerage agencies, but they were so successful that they soon extended their operations back to the sources of supply, namely, production and refining.

The first association was incorporated in Minnesota in 1926 as the Minnesota Cooperative Oil Company, later changed to the Midland Cooperative Wholesale. It was the first cooperative wholesale association in the United States organized primarily to engage in the distribution of petroleum products. Its organization was followed by similar organizations throughout the country. In addition, many existing cooperative wholesale associations began to distribute petroleum products and soon thereafter these products represented a major line.

The importance of such wholesale associations is reflected in the dollar volume of sales figure compiled by the Farm Credit Administration for 17 major wholesale cooperatives. The combined value of supplies sold at wholesale amounted to $220,360,873 for the

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year ending in 1942. Petroleum products represented $47,966,314 of this volume. It is further estimated that all cooperative wholesales handled petroleum products in 1942 amounting to 655,000,000 gallons of refined petroleum fuels, 10,792,000 of lubricating oil, and 12,929,000 pounds of grease.

As early as 1934, three wholesale associations operated their own oil compounding plants and laboratories. At the close of 1943, nine cooperative wholesales owned 10 refineries with an estimated daily capacity of more than 46,000 barrels, hundreds of miles of pipe line, seven oil compounding plants, grease plants, and oil producing wells.

The real pioneer in cooperative petroleum production and refining was the Consumers Cooperative Association, of North Kansas City, Missouri. It organized a subsidiary, the Cooperative Refinery Association, to construct the first cooperatively owned refinery in the United States at Phillipsburg, Kansas, in the year 1939. Operation of the 3000-barrel refinery began in 1940. The refinery paid for itself in two years.

Two additional subsidiaries, the Cooperative Oil Producing Association and the Cooperative Pipe Line Association, were organized to engage in oil exploration and production and to transport the oil to the refinery. These subsidies now own three refineries, 867 miles of pipe line and 289 oil wells.

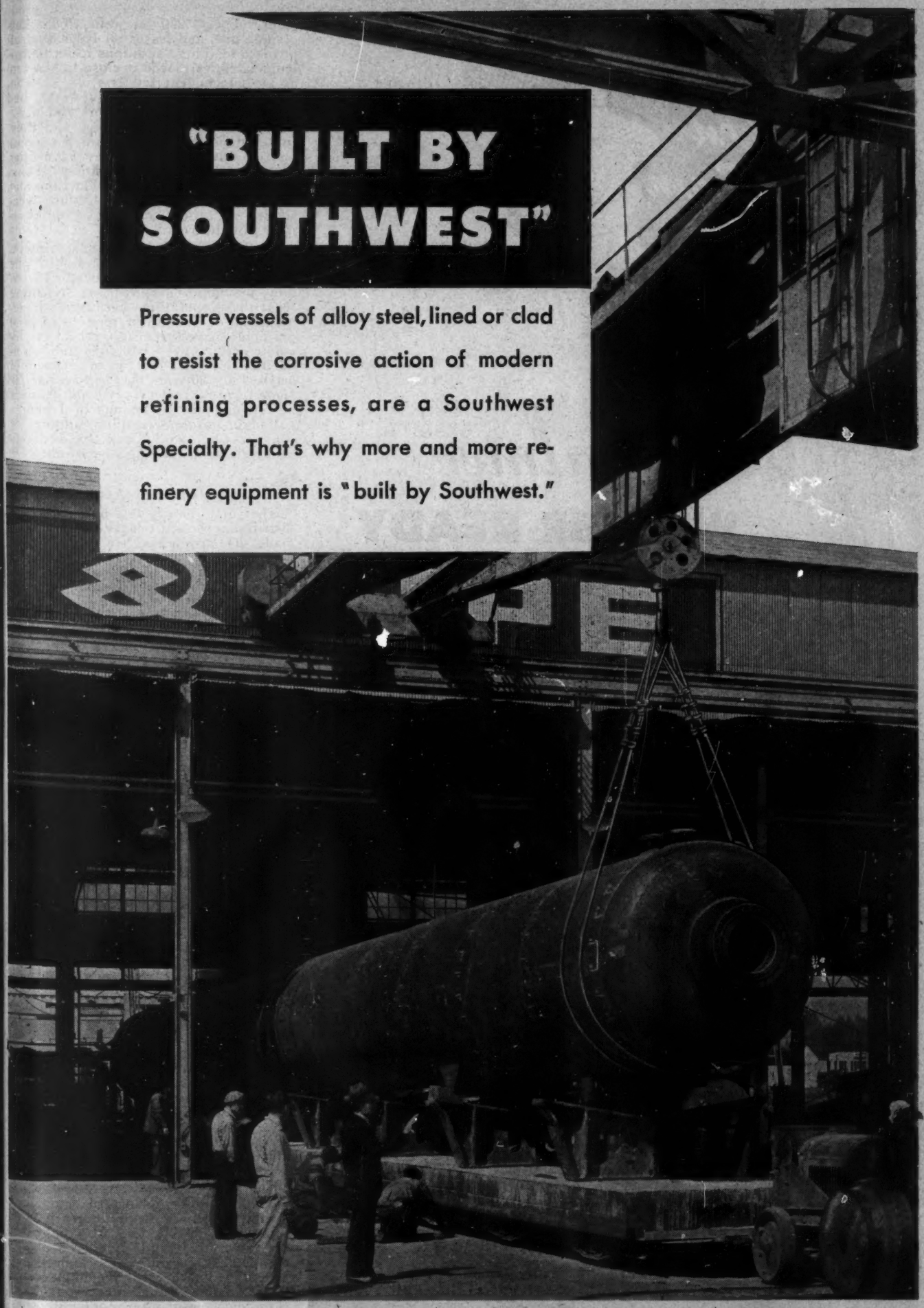
CCA purchased the Terry Carpenter 1500-barrel refinery at Scottsbluff, Nebraska, in 1942, at a cost of $750,000, and National Refining Company's 13,500-barrel plant at Coffeyville, Kansas, in 1943, at a cost of $4,000,000. It also sponsored formation of National Cooperative Refinery Association and, through it, owns a part interest in the former Globe Refinery.

Rapid Growth

The association began operations in 1929 with seven members and $3000 capital. At the end of 1943, its membership had increased to 749 and its net worth to more than $2,800,000. Total sales amounted to $309,000 in 1929 and more than $15,000,000 in 1943. The majority of its present net worth represents profits retained in the capital structure.

At the end of 1942, cooperatives owned four refineries. In addition to the two refineries owned by Consumers Cooperative Association, the Indiana Farm Bureau Cooperative Association and the Farmers Union Central Exchange of St. Paul had purchased a 3000-barrel plant and a 500-barrel plant, respectively. The former located at Mount Vernon, Indiana, and the latter at Laurel, Montana.

In addition to purchase of the Globe Refinery by the National Cooperative Refinery Association about the middle of 1943, the following refinery purchases were made during 1943: A refinery with a 4500-barrel capacity was purchased by Midland Cooperative Wholesale. Farmers Union Central Exchange also entered the field of refining by the purchase of a million-dollar plant with capacity of 96,600 gallons of gasoline per day. In addition, it produced codimer, a component used in aviation gasoline and synthetic rubber. Missouri Farmers Union bought a petroleum refinery, 115 miles of pipe line, land and storage facilities for $321,000. Consumers Refinery Association purchased a 10 million-gallon oil refinery and an 81 million-gallon petro-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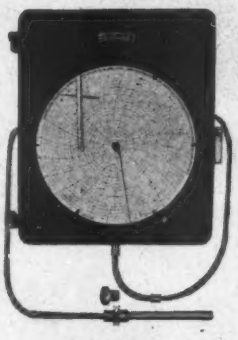

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leum refinery, 270 oil wells, 768 miles of pipe line, and leases on 104,408 acres of oil land. These additions to its petroleum facilities placed it close to the top as an independent refinery.

Cooperators, beyond question, believed that production offers the most profitable field of operations, and they fully intend to capitalize on the competitive advantage that they have over their tax-burdened opposition. Their spectacular entry into production and refinery operations in 1943 far overshadowed other cooperative developments of the year.

Furthermore, cooperators contend that they have merely scratched the surface and have not yet begun to obtain maximum economies resulting from these operations because their acquisition of refineries, pipe lines, and oil fields have been too recent a development. They contend and confidently expect "that in a matter of maybe 15 or 20 years *they will become the biggest single factor in the oil business* . . . they point to savings of 1 cent a gallon in gasoline retailing, another ¼ cent in wholesaling, and 2½ cents in producing and refining operations."

Local Petroleum Associations

The first petroleum purchasing or distributing cooperative association made its appearance in Cottonwood, Minnesota, in July of 1921. Since that date, the gas and oil cooperatives have expanded until — "Approximately 20 percent of all petroleum fuels used on American farms during 1942 were purchased through farmers' cooperatives."

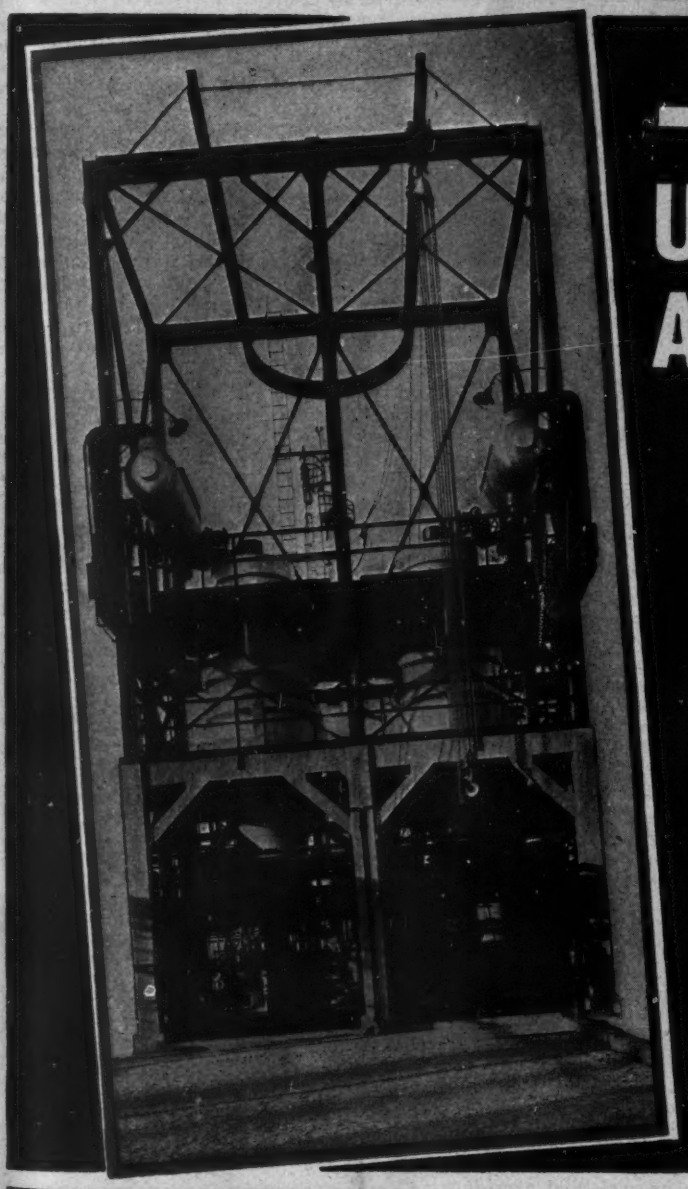
Total retail distribution of gasoline and other petroleum fuels by cooperative associations for the year 1942 has been estimated at about 728 million gallons, of which approximately 655 million gallons represent consumption by farmers. Lubricating oil distribution was estimated at 12,191,000 gallons and grease at 14,365,000 pounds for the same period. Only about 10 percent of petroleum products distributed at retail by cooperatives is obtained through private channels. The remainder is purchased from regional wholesales.

Bureau of Labor Statistics of United States Department of Labor estimates that there were 1150 associations primarily engaged in the distribution of petroleum products in 1936, with 325,000 members and a business of $69,985,000, and in 1942 an estimated 1400 comparable petroleum associations, with 650,000 members and an annual business of $197,000,000.

Experience has shown that cooperatives are influenced by the same economic factors as private enterprise, but that they have prospered disproportionately as a result of the artificial stimulants applied by a benevolent government. Exemption from income and excess profits taxes and business regulatory laws, together with governmental credit and special privileges, have enabled the petroleum cooperatives to absorb many independent distributors and refiners.

With some semblance of competitive equality, the petroleum industry could offer little objection to the competition of cooperatives and should be able to compete successfully. It cannot, however, pay its share of the high cost of war and at the same time, through taxation and many other competitive disadvantages, support its opposition.

More Than 100 STRATCO CONTACTORS



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Rathbone, Boyer Advance As Smith Joins Standard Oil Company (N. J.) Board

Chester F. Smith resigned as president of Standard Oil Company of New Jersey to become a member of the board of directors of Standard Oil Company (New Jersey); M. J. Rathbone resigned as president of Standard Oil Company of Louisiana to become president of Standard Oil Company of New Jersey, and M. W. Boyer was named executive vice president of Standard Oil Company of Louisiana, in a shift of executive personnel of Standard Oil Company (New Jersey) and its subsidiary companies which moved Eugene Holman to the presidency of the parent organization replacing R. W. Gallagher, who becomes board chairman. Frank W. Abrams was made a vice president, and Jay E. Crane, treasurer, was made a director of the parent company.

Smith joined the engineering department at Bayonne refinery in 1913 and has been president of the refining subsidiary since 1936.

Rathbone has spent all of his 23 years of experience with Standard Oil Company of Louisiana which he joined as a draftsman in 1921. He was born in 1900 at Parkersburg, West Virginia, where his father was manager of a Standard Oil Company of New Jersey refinery, attended Lehigh University, and was a second lieutenant in World War I. He has been responsible for many of the innovations that have made the Baton Rouge refinery one of the largest integrated refining and petroleum chemical plants in the world. Among other developments, this includes high-pressure hydrogenation for large-scale production of 100-octane gasoline blending agent and commercial production of butadiene and synthetic rubber from petroleum.

M. J. RATHBONE

Boyer was born in Muncie, Indiana, 42 years ago, and has a master's degree in chemical engineering from Massachusetts Institute of Technology. He started with Standard Oil Company of Louisiana on April 1, 1927, as chemical engineer in the research laboratory at Baton Rouge. In 1930 he became chief chemical engineer of the research laboratory, and in 1931 advanced to head of the technical division. He became general superintendent of the refinery in 1933, and became assistant general manager of manufacturing upon election as a director of the company in 1935. He has been vice president and general manager since October 2, 1936, and as executive vice president continues as general manager of the manufacturing department.

Gallagher, who came to the parent company from East Ohio Gas Company in 1933, became chairman of the board in 1942 and was elected president in 1943 upon the death of W. S. Farish. He continues also as chairman of the executive committee.

Holman joined Humble Oil & Refining Company in 1919, and advanced to chief geologist before going to New York in 1929 as assistant to E. J. Sadler, then vice president. He became an executive of several foreign operating subsidiaries of Standard Oil Company (New Jersey) and vice president of the parent company in 1942, and a member of the executive committee in 1943.

Crane came to the company in 1933 as assistant treasurer and has been treasurer since 1936.

Abrams has been a member of the board since 1940, having joined the company's refining division in 1914 and advancing to president of Standard Oil Company of New Jersey before joining the parent company.

William F. Thiede, general superintendent of the Bayonne refinery of Standard Oil Company of New Jersey, has been named assistant manager of that company's New Jersey Works.

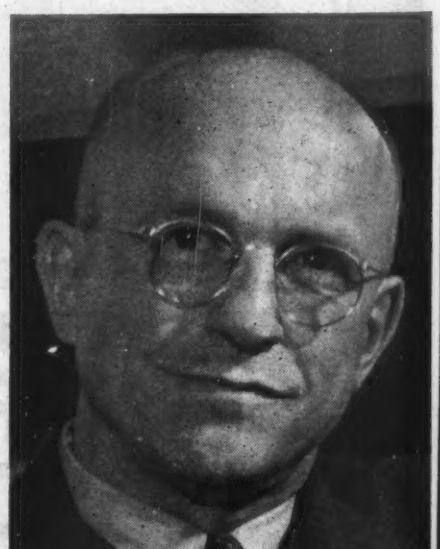
Stanley A. Wuchter, assistant general superintendent of the Bayonne plant, has been made general superintendent, and George A. Esty, former process superintendent at the same plant, in turn, succeeds him as the new assistant general superintendent.

The New Jersey Works, which includes the Bayonne, Bayway and Eagle operations of the company, is headed by George H. Mettam, manager.

Thiede started at Bayway plant in 1912. In 1926 he was appointed assistant superintendent in charge of atmospheric distillation and oil movements and storage, and was made assistant general superintendent in 1936. Two years later he was transferred to Bayonne as acting general superintendent, succeeding to the full title six months later.

Wuchter began his association with the company December, 1920, in the general engineering department at Bayway. In 1922 he was transferred to the Bayonne engineering group and five years later was made assistant master mechanic. Except for a year spent at Bayway as mechanical superintendent, he continued in the former position until 1936 when he was made assistant to the general superintendent at Bayonne, becoming assistant general superintendent in June, 1937.

Esty, who has been process superintendent at Bayonne, joined the company in 1916. After two years in the Navy he returned to Bayonne in 1919 as foreman of the No. 3 refinery. In 1924 he was made foreman of the pitch plant and was transferred two years later to the No. 2 refinery. During 1927 he spent several months as member of a company committee engaged in standardizing refinery operations. In 1928 he was made assistant process superintendent



M. W. BOYER

Nominations Made for Officials of CNGA

Nominations for officials and directors of California Natural Gasoline Association were announced June 3 as a part of the program of the summer frolic program at Rio Hondo Country Club. Those nominated are: Clare D. Gard, assistant to the manager of the gas department, Union Oil Company, president; Marion L. Arnold, superintendent of the gas department, Richfield Oil Company, vice president.

Nominations for directors are: M. L. Arnold, V. L. Cassady, Lomita Gasoline Company; D. A. Cushman and Oliver C. Field, O. C. Field Gasoline Company; A. Hegeman, Clark Brothers Company; W. H. Kraft, Honolulu Oil Corporation; E. A. McAllister, Western Gulf Oil Company; William Moeller, Jr., Southern California Gas Company; N. H. Mull, The Texas Company; J. H. Sargeant, Kettleman Hills North Dome Association; J. B. Taylor, Signal Oil & Gas Company; J. B. Wharton, Belridge Oil Company; J. A. Campbell, J. A. Campbell Company; F. E. Coyle, Tide Water Associated Oil Company; F. F. Doyle, Pacific Gas & Electric Company; R. E. Foss, Barnsdall Oil Company; W. A. Kirk, California Southern Oil Company; R. S. Lytle, Los Nietos Petroleum Company; H. M. Paulsen, Bankline-Norwalk Company; George Sowards, Ohio Oil Company; G. C. McLaren, T. L. Taggart and D. M. Wolfe, Standard Oil Company of California.

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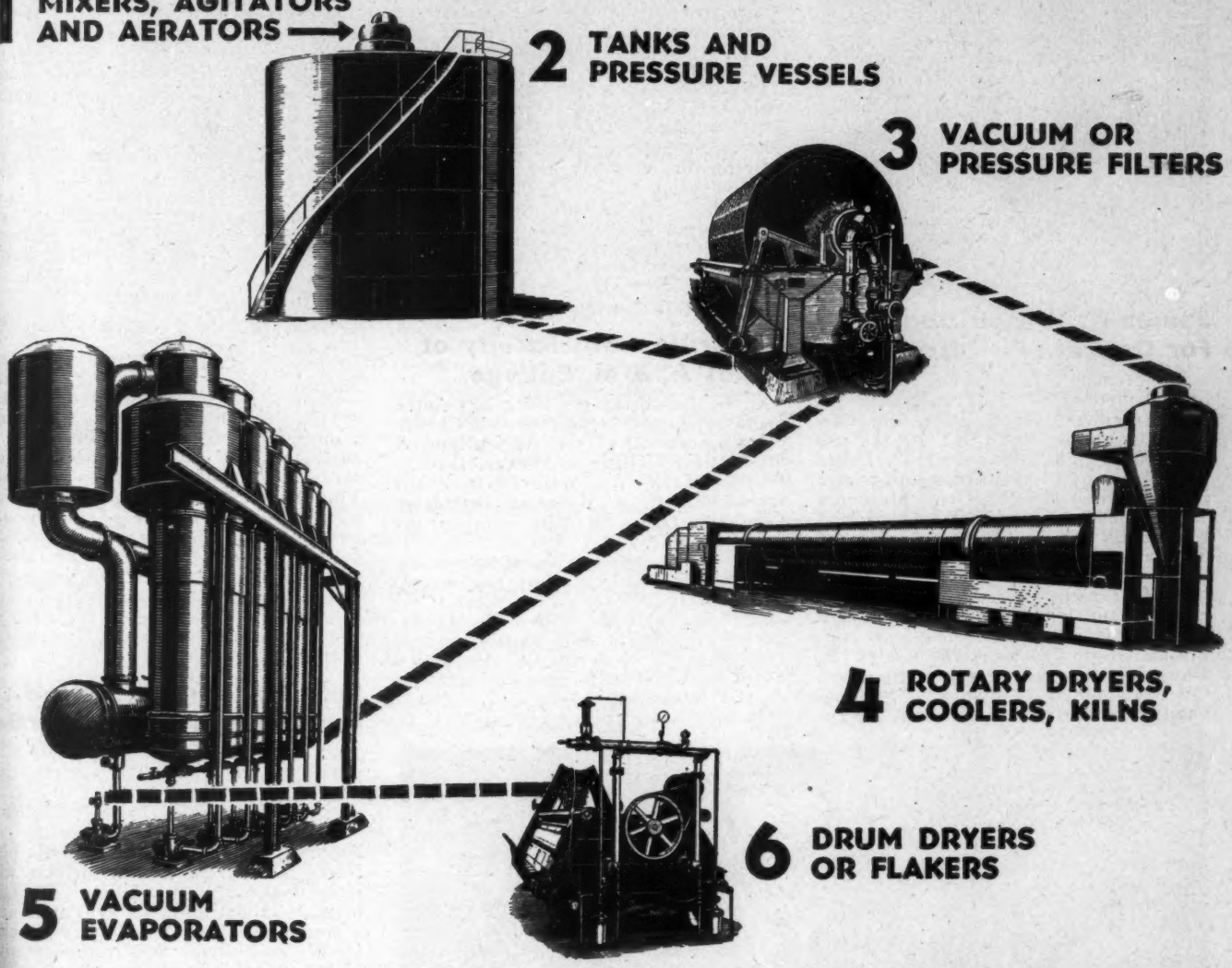

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and in May, 1931, process superintendent. He has continued in that position with the exception of two years, 1932 to 1934, spent surveying operations in Sumatra and starting the Port Jerome refinery in France.

Exceeding all previous records, Standard Oil Company (New Jersey)'s world-wide crude oil production and refinery runs reached an all-time high during the first half of this year. Gallagher reported to stockholders at the meeting in New York, that today the company is averaging more than 840,000 barrels of oil daily, about 18 percent more than the previous peak record of 711,000 barrels in 1941. The company's domestic units are responsible for most of the increase, yielding oil at a rate 60 percent higher than in 1941.

For the first time in the company's history, its world-wide refinery runs have topped 1,000,000 barrels daily. For the first quarter this year, the rate was 1,026,152 barrels, or 13 percent beyond the previous high of 910,490 barrels, which was also in 1941. Domestic refineries show most of the increase.

James A. Wilson Honored For Optical Test Discovery

Honored as the discoverer of a new optical method for quickly determining the ingredients of aviation gasoline, synthetic rubber and TNT by the use of infrared light waves in 1942, James A. Wilson, a petroleum research worker in Esso Laboratories, was presented with a gold medal and $500 cash award by Frank A. Howard, president of Standard Oil Development Company, at a ceremony at Bayway, May 27.

Wilson, whose discovery reduces a complex and lengthy analysis to an almost immediate calculation, was congratulated on his work by G. H. B. Davis, director of research of Standard Oil Development Company, at the presentation ceremonies attended by executives of the company and members of the technical departments.

Narrow infrared beams to identify components of petroleum fractions which go into high-octane gasoline, toluene, butadiene and other war products, have been used experimentally by the petroleum industry for the past three years. By passing beams of light of narrow infrared wave lengths through the samples being analyzed, it is possible to identify them. Lights of certain wave lengths are absorbed by the various ingredients in the sample. By recording the way in which light beams pass through the sample, the laboratories are able to tell which items are in the sample.

Originally presented to the Coin-Your-Ideas committee of Standard Oil Development Company, Wilson's invention brought an initial award of $25 pending further study. By March, 1944, the potential value of the idea was realized. A supplemental award of $200 was made and the idea recommended for consideration by the Central Coin-Your-Ideas committee of Standard Oil Company (New Jersey) and affiliates. The committee voted the $500 award.

Kirkbride Joins Faculty of Texas A. & M. College

C. G. Kirkbride has been appointed professor in the Department of Chemical Engineering of the Agricultural & Mechanical College of Texas, College Station, Texas. He resigned from the research staff of Magnolia Petroleum Company, Dallas, in order to accept the appointment.

His duties will include graduate instruction in the chemical engineering field and the direction of research required for both M. A. and Ph. D. degrees. A considerable portion of his time also will be devoted to developing cooperative research projects with industrial organizations.

In estimating the appointment, J. D. Lindsay, head of the department, said:

"The appointment marks an expansion of the graduate program of the institution. Professor Kirkbride has had many years of industrial experience. This includes process design and technical service on most of the modern petroleum refining processes such as catalytic and thermal cracking, alkylation, isomerization and polymerization. It makes him particularly well qualified to aid in the development of Texas' resources through the application of chemical engineering."

C. G. KIRKBRIDE

Butylene Output Shifted From Rubber to Aviation Gas

By diverting part of its butylene output from synthetic rubber to 100-octane gasoline, the refining industry made ready to produce an extra million barrels of aviation fuel during July and August. The shift followed frantic pleas from military authorities, which were relayed through the Office of Petroleum Administration for War and finally a conference between military officials, PAW executives and representatives of the industry in Washington June 29.

Following the conference Administrator Ickes assured the military with this statement:

"The oil industry has never failed to deliver in this war and it will not fail to do even the impossible now."

William R. Boyd, chairman of PIWC added:

"The industry will make good any check drawn upon it."

Previously Bradley Dewey, rubber director, had authorized diversion of 400,000 barrels of butylene from butadiene manufacture into alkylation processing. This with proper amount of butane is calculated to make sufficient alkylate for assuring 1,000,000 barrels additional 100-octane gasoline.

The diversion will end September 1, when petroleum butadiene plants will be returned to making ingredients for synthetic rubber. Meanwhile Dewey gave the assurance that the cut back in butadiene will have no effect on finished rubber products, since manpower shortage in making finished rubber goods is

F. A. Howard, left, president of Standard Oil Development Company, James A. Wilson, and W. J. Sweeney, associate director, research division, of Esso Laboratories of Standard Oil Development Company. Wilson is being given a gold medal and $500 cash award for his discovery of an optical method for testing specialized petroleum ingredients.

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Wagner CP totally-enclosed fan-cooled motors are designed to operate under adverse conditions in atmospheres that contain dust, dirt, abrasives, steel chips, filings, acid fumes, and other harmful elements.

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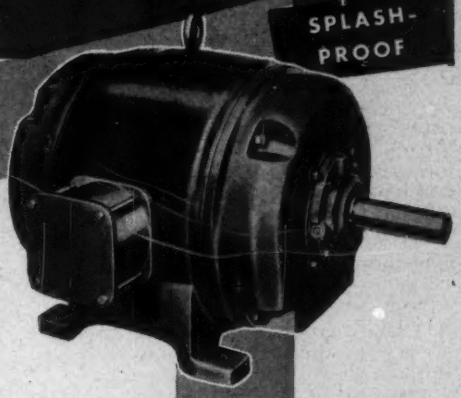

Wagner splash-proof, squirrel-cage polyphase motors are built to operate dependably in locations where they are subject to splashing water, oil, or other liquids. They are widely used in unprotected outdoor locations, being designed with complete self-protection against rain, snow and sleet.

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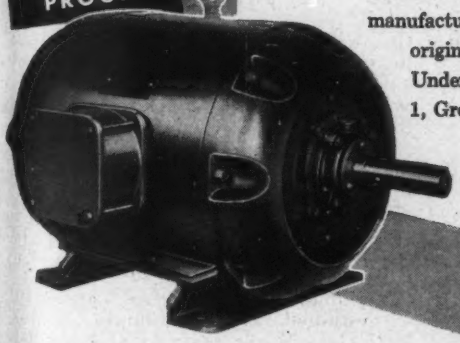

Wagner explosion-proof polyphase motors are designed to operate in locations where "flammable volatile liquids, highly flammable gases, mixtures or other highly flammable substances are handled or manufactured, used or stored in other than original containers." Approved by the Underwriters' Laboratories for Class 1, Group D hazardous locations.

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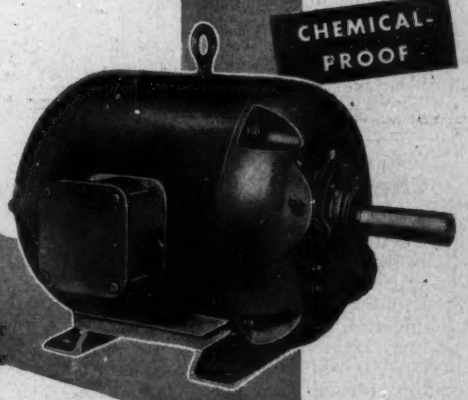

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such that the supply of crude synthetic is in excess of current requirements.

The plants affected by the diversion of butylene from butadiene into aviation motor fuel are: Cities Service Refining Corporation, Lake Charles; Humble Oil & Refining Company, Baytown; Neches Butane Products Company, Port Neches; Phillips Petroleum Company, Borger; Shell Chemical Company, Torrance; Sinclair Refining Company, Houston; Standard Oil Company of Louisiana, Baton Rouge.

Robert P. Patterson, undersecretary of war, said "100 octane aviation gasoline is being consumed in unprecedented quantities and despite the fact that high-octane production is on its current schedule, we are under the necessity of stepping up shipments of this product to the fighting forces overseas."

Excellent flying weather and low resistance from the German air force were unofficially credited with contributing to the gasoline shortage in Europe. Because the combined air forces of the United Nations can fly and bomb almost at will, they are using abnormal amounts of motor fuel.

Seriousness of the situation was evident in mid-June when Bruce K. Brown, assistant deputy administrator, PAW, advised the industry as follows:

"Cables from commanding generals in active theatres demand increased shipments of aviation gasoline.

"The all-out air effort has resulted in serious reductions in combat theatre stocks. Army Air Forces, Royal Air Force and Navy are presenting most urgent pleas for immediate shipments above and beyond all previous estimates. It will be necessary to ship up to 50 percent more fuel than previously estimated for consumption in some of the most active theatres in the next two or three months."

The conference in Washington between oil-company executives, PAW officials and military personnel was an off-the-record affair, but it was intimated that the program proposed building reserve supplies of 100-octane gasoline to double previous estimates.

Exact production figures on this gasoline are not made public. In Texas City in June, however, Ralph K. Davies, deputy petroleum administrator, said that daily output would reach 500,000 barrels daily by July 1. This output will be accomplished with the construction program for 100-octane gasoline but 80 percent completed, as reported by PAW June 30. At that time 450 refining, natural-gasoline and cycling plants were contributing to this product.

In the construction program instituted especially for 100-octane gasoline, 150 units are in operation and 39 will be completed later this year. A break-down of the program showed 56 alkylation units completed and 13 building; 26 isomerization units completed and 9 building; 26 fluid catalytic cracking units completed and 7 building; 10 thermofor catalytic cracking units completed and 6 building; 9 Houdry catalytic cracking units completed and 1 building; 4 Houdry units revamped; 2 hydrogenation units completed and two dehydrogenation units built and 15 miscellaneous units built and 1 building.

Kightlinger Heads Gas Measurement Short Course

Earl Kightlinger of Arkansas-Louisiana Gas Company, Shreveport, was named chairman of the 1945 session of the Southwestern Gas Measurement Short Course, at the concluding session of the 1944 meeting at Norman, Oklahoma, early in June. Max Watson, the retiring chairman, becomes a member of the executive committee. W. H. Woods, Gulf Oil Corporation, Houston, was elected chairman of the practical methods committee. Proceedings of the 1944 course will be distributed as a bulletin September 1. Total enrollment was 545, of which 80 percent were attending their first session of the course, indicating the number of new personnel engaged in gas measuring, and further intensifying the need for the instruction to be had from this annual three-day training course.

EARL KIGHTLINGER

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2-Decalone
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7,8-Dihydroxy-1,4-naphthoquinone
8-hydroxy-1,4-naphthoquinone
Methyl phosphine
Methyl azide
Propyl fluoride
Thio alcohols containing 8-18 carbons, pri, sec. or tert.
1,1,1-Trichlor acetone
1,1,1,3-Tetrachlor acetone
Vinyl monochlor acetate
Vinyl trichlor acetate

Robinson Heads Barber Manufacturing Department

Barber Asphalt Corporation has announced appointments of Phillip M. Robinson as general manager of its manufacturing department, and William L. Kallman as general manager of its sales department.

Robinson is a chemical engineer who worked for Gulf Refining Company and for Pennzoil Company between 1922 and 1940. In December, 1940, he joined

P. M. ROBINSON

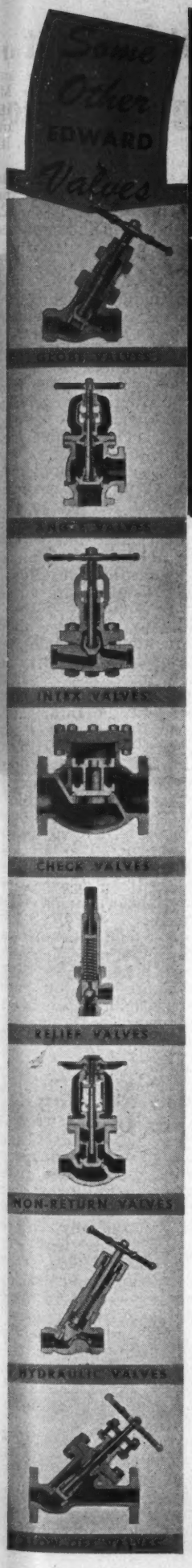
the National Defense Advisory Commission as Assistant to Dr. R. E. Wilson, head of the Petroleum Division, and later became acting director of refining in the Petroleum Administration for War. In April, 1943, he resigned to become assistant to the vice president in Charge of Manufacturing for Southport Petroleum Company to direct construction and operation of a large 100-octane gasoline plant at Texas City, Texas.

Kallman graduated from Yale in 1916 and studied law at Columbia University. He was a captain of field artillery, serving overseas, in the first World War and has been associated with The Texas Company ever since, filling all positions in the sales department from stenographer and salesman to Eastern sales manager. For the past two years, he has been on loan to the Petroleum Industry Committee as executive secretary to the supplies and distribution committee.

While Barber Asphalt Corporation at present is engaged in various war activities, its operations normally include asphalt from Trindad, petroleum refining at Barber, New Jersey, and mining of gilsonite in Utah.

Frame Heads PAW Refining Division

A. P. Frame, vice president of Cities Service Refining Corporation, Lake Charles, has been appointed Director of Refining, Petroleum Administration for War. His selection fills the place held from December 1942 until June 1944 by E. D. Cumming, who has resumed his



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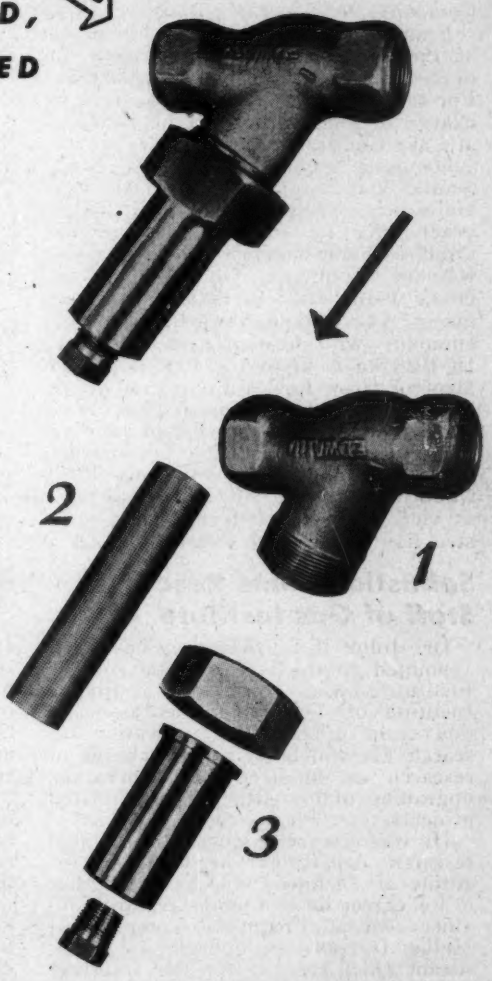

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A. P. FRAME

duties as vice president of Shell Oil Company, New York.

Frame has taken leave from his duties at the new plant of his company in order to fill the post at Washington. For the past two years he has been in charge of construction of the facilities at Lake Charles.

He is a native of Wallace, Nova Scotia, and a graduate of Dalhousie University, Halifax, in 1921. Three years later he joined Cities Service group as plant engineer for Empire Oil Refining Company, Okmulgee, Oklahoma. From 1927 to 1928 he was engineer of the refining department of this company with headquarters at Tulsa. In 1928 he went to the Petty's Island plant of Crew-Levick Company, where he was superintendent until 1938.

He was assistant director of refining for Cities Service Refining Corporation from September 1938 until July 1942, when he became chief engineer as well as vice president, and supervised construction of the Lake Charles plant.

Sebastian Joins Research Staff of Gas Institute

Dr. John J. S. Sebastian has been appointed to the research staff of the Institute of Gas Technology at Illinois Institute of Technology, as associate supervisor of coal and gasification research. He will be in general charge of research on fluidized gas generation, upgrading of low Btu gas, and related projects.

He was research associate in the coal research department at Carnegie Institute of Technology 11 years. Earlier in his career he worked as research engineer for the Koppers Company at Mellon Institute, Pittsburgh, and as assistant chief chemist for the Interlake Iron Corporation, Chicago. Immediately prior to his appointment, he was general manager of the Balsam Mining and Manufacturing Company.

Dr. Sebastian is a graduate of the Royal Polytechnic Institute of Budapest, and received his doctor of science degree at Carnegie Institute of Technology.

PAW Inquiry Indicates Interest in Plant Construction Beyond War Emergency Period

Through its division of refining, the Petroleum Administration for War is seeking to learn the extent of plant expansion and rehabilitation when materials again are available. The letter to all refiners from E. D. Cuming, Director of Refining, makes no promises and sets no dates. It simply gives each refiner opportunity to make known what he would like to do in construction and rehabilitation.

Among the suggestions is that further expansion be through private capital and without the assistance of accelerated tax amortization or promise by government to buy output.

The letter follows:

"Up to the present time the refining industry has been essentially restricted to new construction work which represented the barest minimum which would achieve the end of supplying the most critical war products. This policy has been necessitated by the extreme demands for construction materials and construction labor which the war placed on the country's economy.

"As the present 100-octane construction program is rapidly nearing completion, it has been becoming more apparent that at some time in the future a relaxation in the use of construction materials might be feasible. To that end the refining division of the Petroleum Administration for War believes that a concrete program of desired refinery construction should be available; so as to take immediate advantage of any such possible relaxation by the War Production Board.

"The types of new construction projects which appear particularly advantageous to us at the present time include the following:

"1. Installation of new facilities which will produce higher yields of better quality refined products from a barrel of crude. This should include the construction of new facilities for improved or more efficient production of critical war products as a back-up for possible requirements as well as other less urgently needed war products and other essential civilian and industrial products. Special attention is directed to the installation of new facilities which could (a) be applied, either directly or with subsequent additions, to the production of increased 100-octane quantities or improved qualities; (b) produce additional highly refined lubricating oils; and (c) furnish additional refined or semi-refined product storage capacity.

"2. The adaptation of refinery facilities to processing additional high-sulfur crude, so as to take advantage of the only presently assured source of additional readily available crude supply.

"3. The installation of research and development facilities, looking forward to a more efficient utilization of the known crude supplies and the production of better quality end products.

"4. The installation of more efficient utilities and service units as replacements of or additions to present overtaxed or antiquated facilities.

"We would like to have you give serious consideration to this and other types of supplementary refinery construction programs and, at your earliest convenience, submit a short descriptive proposal outlining the type of facilities which appear advantageous to your company and to the refining industry. Such an outline should include:

"1. Location and a brief description of the facilities.

"2. Estimated total cost.

"3. Effect of such facilities on crude oil and other charge stock requirements and on product yields and qualities.

"4. Advantage of such facilities from standpoint of war products.

"5. Advantage of such facilities from standpoint of contribution to civilian economy during the war.

"6. Advantage of such facilities from postwar standpoint.

"We believe that such a supplementary refinery-construction program should necessarily be limited to projects which would be constructed entirely with private capital and without any government obligation to underwrite any investment through the accelerated tax amortization procedures or to purchase any products.

"We would like to have the above preliminary information, regardless of whether or not you have a priority application on file. Submission of such information will not bind you to undertake construction and the information submitted will be regarded as confidential.

"When and if a supplementary program of this type is adopted we expect to give first consideration, as to projects of a given type, to those which were first submitted in up-to-date detail, including a PAW Form 30 application. We wish to emphasize that projects, to be so considered, will be restricted to those which have been soundly and carefully estimated.

"In closing we would like to emphasize that this is an approach to a problem which we believe the refining industry should be prepared for, but it does not reflect any definite promise as to the time when such a program could be fully initiated. Your cooperation is appreciated."

Hopper Heads Refining Operations for Union

Basil Hopper and Sam Grinsfelder have been elected vice presidents of the Union Oil Company of California.

Long identified with the manufacturing operations of the company, Hopper first became associated with the company June 18, 1923, and has served in the company's research and development departments, as well as in manufacturing operations at the company's three refineries. He studied chemical engineering at the University of California, finishing at the California Institute of Technology in 1923. As vice president he is in charge of all manufacturing of the company.

Grinsfelder joined Union Oil Company as assistant geologist of the Rocky Mountain division, in 1922. In 1927 he went to Texas as assistant manager of that division, returning to Los Angeles in 1931, where he held various positions in the field department. In 1939 he re-

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- YOUNGSTOWN SHEET & TUBE CO. — Pipe
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- CRESCENT TOOL CO. — Wrenches, Pliers, Screw Drivers, Punches, Chisels
- MID-WEST ABRASIVE CO. — All types of Abrasives
- CORTLAND GRINDING WHEEL CORP. — Grinding Wheels, Chucks
- TOLEDO PIPE THREADING MACHINE CO. — Pipe Dies and Threading Machines
- THE DUFF-NORTON MFG. CO. — Jacks
- ERIE TOOL CO. — Wrenches, Vises, Pipe Cutters
- GATES RUBBER CO. — V-Belts, Rubber Goods
- CLOVER MFG. CO. — Abrasives
- BETHLEHEM STEEL CO. — Wire Rope, Sheets, Nails

QUALITY PRODUCTS. The list of outstanding manufacturers shown at the left tells its own story of the quality products we distribute.

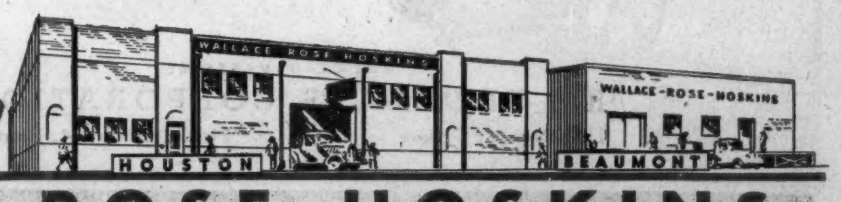
SERVICE THAT SAVES YOU TIME . . . THAT HELPS YOU IN AN EMERGENCY.

Through the years, it has been our privilege to serve a growing number of oil industry customers. Repeat business in increasing volume from these customers is proof that our supply house provides them with the quality products they demand, and that they appreciate that extra value we give with these products—all-out service . . . day and night.

OUR AMPLE LINES of oil industry products are distributed from large warehouses in Houston and Beaumont.

CALL US for speedy service and quality products.

W R H



Wallace ROSE-HOSKINS

910 NAGLE STREET, HOUSTON • 1365 CROCKET STREET, BEAUMONT

CALL US FOR SPEEDY SERVICE AND QUALITY PRODUCTS

R-S Valves

Installed in

Cities Service New Plant

Lake Charles, La.

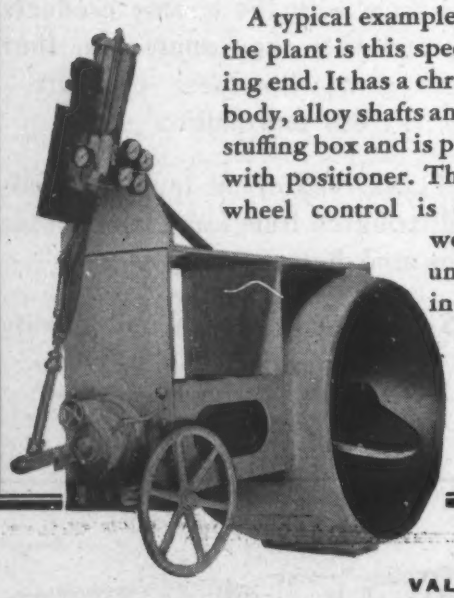
This new 100-octane gasoline and butadiene plant, now operating deasphalting, desalting, topping and cracking units, will produce daily enough high-octane gasoline to power a raid of 1000 bombing planes over Germany. Butadiene for more than 12 million synthetic rubber tires will be turned out each year.

R-S Butterfly Valves are a "natural" wherever simplified and quick control or shut-off of volume and pressure are required. (Remember that four to six revolutions of the handwheel completely open or close an R-S valve vane.)

No. 582

A typical example of the R-S valves installed in the plant is this special 36-inch valve with welding end. It has a chrome-moly vane, carbon-moly body, alloy shafts and bushings, finned lubricated stuffing box and is powered by hydraulic cylinder with positioner. The auxiliary heavy-duty handwheel control is equipped with self-locking worm and gear. Declutching unit permits manual operation in case of power failure.

Ask for Catalog.



15 to 900 psi

VALVE DIVISION

R-S PRODUCTS CORPORATION

120 Berkley Street • Philadelphia 44, Penna.

R-S Streamlined BUTTERFLY VALVES

turned to Texas as manager of field operations, which job was expanded to cover all Gulf operations in 1943. He will continue to direct the work in Texas, Louisiana, Florida, Mississippi and Alabama.

No Priority Is Needed For Resale of Equipment

Amending Preference Rating Order P-98-c, covering materials redistribution program No. 2, to conform with changing material requirements, PAW officials have emphasized that oil operators do not need—and should not use—priority ratings to purchase either new or used equipment from another operator or from a supplier acting as an intermediary in the resale of equipment.

The amended order, issued by WPB, is designed to correct an impression among some suppliers that surplus materials purchased from one operator could not be resold to another operator unless the latter had an allotment number, symbol or priority rating.

Collins Heads District 1

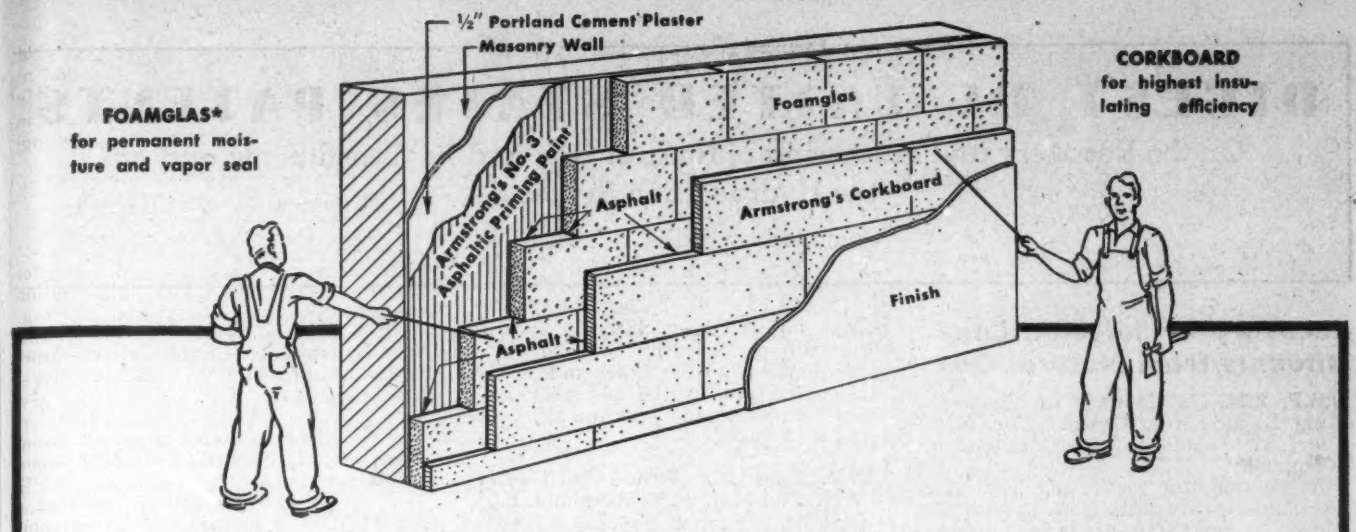
Appointment of J. D. Collins, vice president in charge of sales for Tide Water Associated Oil Company, as director in charge for District 1, succeeding H. W. Dodge, was announced June 5 by PAW.

Collins has had considerable experience with PAW problems as a member of the District 1 distribution and marketing committee.

Perry Superintendent of Two Louisiana Gasoline Plants

R. E. Perry, formerly with Cotton Valley Operators' Committee, Cotton Valley, Louisiana, has been appointed general superintendent of Glen Rose Gasoline Company's plant at Rodessa, Louisiana, and of Claiborne Gasoline Company's plant at Lisbon, Louisiana, according to an announcement made by Paul M. Raigorodsky, manager of the companies. Perry has opened the companies' office in the First National Bank Building, Shreveport.

R. E. PERRY



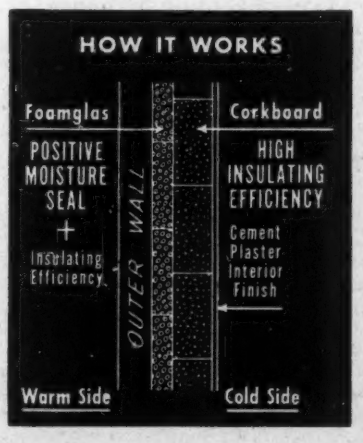
ARMSTRONG ANNOUNCES A NEW LOW-TEMPERATURE CONSTRUCTION

for permanently high insulating efficiency

A NEW type of low-temperature insulation construction that is positively and permanently sealed against moisture infiltration has now been developed by Armstrong. It combines Armstrong's Corkboard with Foamglas and takes advantage of the best properties of both insulations.

It is essentially standard corkboard construction with the addition of an outer shell of Foamglas to perform the sealing function.

Foamglas is well equipped to do this job since it is glass in foamed or cellular form with each tiny cell completely isolated from adjoining cells. Hence the material is absolutely moistureproof, vaporproof, and fireproof.



The use of Foamglas in the construction thus fortifies the natural moisture resistance of corkboard and supplements its well-recognized high thermal efficiency. The construction assures permanently high operating efficiency.

FOR COMPLETE INFORMATION about this new construction—including engineering drawings and erection specifications—write today to Armstrong Cork Company, Building Materials Div., 7507 Concord St., Lancaster, Pa.

*Foamglas—Reg. U. S. Pat. Off. Product Mfg. by Pittsburgh Corning Corp.

ARMSTRONG CORK COMPANY

Insulation Headquarters

DIGEST OF UNITED STATES PATENTS

On the Recovery and Processing of Natural Gas and Its Constituents and on the Hydrocarbon Synthesis

Compiled by HEINZ HEINEMANN

Recovery of Selected Constituents from Natural Gas

U.S.P. 2,242,173. Method for Recovering Liquids from Gases. S. E. Buckley to Standard Oil Development Company.

A method of recovering desirable liquefiable constituents from natural gas which is initially at high pressure within the retrograde-condensation range of said constituents is claimed, which comprises cooling the gas sufficiently to condense said constituents while reducing said high pressure substantially only within the retrograde-condensation range of said constituents at the reduced temperature, and separating the resulting condensed constituents from uncondensed gas.

U.S.P. 2,258,015. Separating Hydrocarbon Fluids. P. C. Keith, Jr., L. R. Hill and G. J. Robertson.

A gaseous mixture containing liquefiable hydrocarbons is cooled to a relatively low temperature, but not below the freezing point of water to condense and remove water. The mixture is then contacted with a drying agent to remove all remaining water and then further cooled to liquefy a portion of the hydrocarbons which is withdrawn. The cold gases are used in heat exchange with the incoming mixture.

U.S.P. 2,262,201 and 2,262,202. Natural Gasoline Absorption and Distillation System. E. G. Ragatz and D. E. McFaddin to Union Oil Company of California.

Natural Gas is contacted with absorption oil, producing an absorption-oil solution containing natural gasoline and fixed gases. A portion of this is heated, introduced into a fractionating column and the vapors countercurrently contacted with the other portion of the fat absorption oil. The desirable natural-gasoline vapors are condensed and the fixed gases withdrawn overhead.

U.S.P. 2,272,503. Contacting Device for High-Pressure Absorption. G. S. Bays to Stanolind Oil & Gas Company.

An apparatus for the absorption of gases such as hydrocarbons from wells under high pressure is described.

U.S.P. 2,273,412. Method of Recovering Hydrocarbons. G. W. McCullough to Phillips Petroleum Company. C. A. 36,3937.

An arrangement of apparatus is described and a process employed for extracting heavier constituents from a mixture of gases by selective absorption, which involves introducing absorbent oil to an absorber, bringing the gas into contact with the absorbent oil therein, steam distilling the resulting enriched absorbent oil, passing the vaporous effluent of the distilling step in contact with water to dephlegmate it to condense fractions having boiling points higher than water, separating the resulting condensate of the dephlegmating step from the water and passing the condensate to the absorber at a point below that at which the absorbent oil is introduced.

U.S.P. 2,284,112. Method of Treating Well Fluids. J. P. Walker and E. V. Foran to Eureca Process Corporation.

A method for recovering liquefiable hydrocarbons from well products by condensation while preventing hydrate formation is described.

U.S.P. 2,284,973. Recovery of Gasoline from Natural Gas. W. C. Dayhuff and J. E. Laurance to Standard Oil Company of California.

Gasoline constituents are recovered from natural gas containing such constituents as well as substantial proportions of lower-boiling hydrocarbons, by passing the natural gas to a liquid absorption medium, absorbing gasoline constituents contained in the natural gas in the absorption medium, treating the absorption medium to cause the vaporization of substantially all of the gasoline constituents absorbed therein as well as some of the lighter fractions of the absorption medium, passing the vapors to a zone of partial condensation wherein the vaporized portions of the absorption medium and a minimum amount of heavier vaporized gasoline fractions are condensed, the uncondensed gasoline constituents being passed overhead and separately recovered, and treating the condensed absorption oil and heavier gasoline fractions, apart from the main body of the absorption medium and gasoline constituents, to separate the condensed absorption medium and heavier gasoline fractions.

U.S.P. 2,295,211. Process of Selectively Recovering Desirable Constituents of Natural Gas. J. L. Hill to Danciger Oil & Refineries, Inc.

Liquefiable constituents of natural gas are recovered according to the invention at high pressure, permitting return of the lean gas to the producing horizon without or with only little repressuring. The gas is preheated and passed to a fractionating zone, where it is scrubbed with a liquid consisting of heavier condensable components of the gas while maintaining the zone under substantially the well pressure of the gas.

U.S.P. 2,306,553. Natural Gas Conditioning Process. B. Miller to Cities Service Oil Company.

Liquefiable hydrocarbons are removed from natural gas by condensation effected by refrigerating the gas, expanding it from a high pressure within the retrograde-condensation range to a pressure suitable for pipeline transportation below the retrograde-condensation range. In the next step, liquid is separated and the gas further expanded to the desired transportation pressure in heat exchange with fresh gas.

U.S.P. 2,320,616. Stabilization. L. Kniel and A. H. Schutte to The Lumnus Company.

A vaporous hydrocarbon mixture is subjected to a plurality of partial condensation stages maintained at progressively lower temperatures.

U.S.P. 2,324,954. Refining of Mineral Oils. W. H. Rupp to Standard Oil Development Company.

An improved process for recovering and separating into narrow fractions a hydrocarbon mixture of low-boiling and readily condensable components from a mixture thereof with non-condensible components is claimed which comprises absorbing the low-boiling readily-condensable components along with some non-condensable components in an absorption oil in a primary absorption zone, separating the rich oil into two fractions, stripping the absorbed components completely from one portion thereof in a primary stripping zone and returning that portion directly to the absorption zone, reabsorbing and concentrating the stripped components in the second portion of the rich absorption oil under fractionating conditions, whereby the desired low-boiling readily-condensable components are vaporized therefrom, fractionating the desired absorbed components into narrow cuts while in the presence of the absorption oil, recovering the second portion of the absorption oil free from absorbed components and returning the same to the primary absorption zone.

U.S.P. 2,330,676. Method of Separating Liquid from Gas. S. E. Buckley to Standard Oil Development Company.

Distillate contained in natural gas at pressure in excess of 1500 pounds per square inch is recovered by passing the gas while maintaining it at its pressure into contact with a liquid hydrocarbon derivative containing a group capable of solubilizing the hydrocarbon in water. The solvent must be relatively low boiling and contain an OH, O, or NH_2 group such as methylalcohol and acetone.

Inhibition of Gas Hydrate Formation

U.S.P. 2,266,981. Inhibiting Formation of Natural Gas Hydrates. B. Miller to Cities Service Oil Company.

A water-soluble volatile fluid without injurious effects upon the materials of the pipe line is added to natural gas in amounts sufficient to lower the water vapor concentration of the gas below the critical value for hydrate formation at the lowest temperature and highest pressure of the line. A monohydric aliphatic alcohol such as methanol is a

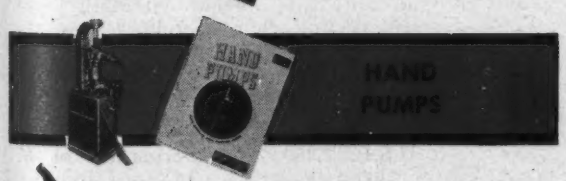
HERE'S WHAT TO DO BEFORE THIS HAPPENS

"WHO MAKES THAT KIND OF FITTING?"
"I THINK X MAKES IT"
"BILL KNOWS, BUT HE IS OUT OF TOWN".
"Y MAKES SOMETHING LIKE IT!"
Send For These Bulletins

Forged Steel Screw End and Socket Welding Pipe Fittings are made by Watson-Stillman in a full line of Elbows, Tees, Crosses, Laterals, Couplings, Reducers, Bushings, Caps, Plugs and Unions for standard or extra heavy pipe lines. All W-S Fittings have uniform wall thickness, maximum wall strength and uniform material characteristics specified and controlled by W-S Engineers. Ask for Bulletin A-3.

For use on standard and extra heavy pipe lines, Watson-Stillman supplies bronze or forged steel Globe Valves, Stop Valves, Angle Valves, Needle Valves and Check Valves of standard types in a wide range of sizes, for screwed, socket welding and flanged connections. Ask for Bulletin A-4.

Watson-Stillman builds standard hydraulic jacks in Independent Pump, Vertical Outside Pump, and Horizontal Outside Pump types. Capacities of 10 to 500 tons. Used by shipyards, contractors, builders, drydock and wrecking companies, machine shops and oil drillers. Ask for Bulletin 710-A.



For operating jacks, small hydraulic tools, and general testing purposes, Watson-Stillman manufactures Single Plunger and Double Plunger Hand Pumps with large, medium and small tanks. Ask for Bulletin 240-A.

On all sorts of construction and maintenance jobs, Watson-Stillman Wire Rope Shears are time-saving equipment. Also suitable for cutting iron bars and rods. Ask for Bulletin 740-A.

For quality at no extra cost specify Watson-Stillman when you sell fittings, valves, jacks, pumps and shears. The Watson-Stillman Co., Roselle, N. J.

WATSON-STILLMAN
DISTRIBUTOR PRODUCTS DIVISION

DESIGNERS AND MANUFACTURERS OF FORGED STEEL FITTINGS, VALVES, AND HYDRAULIC EQUIPMENT

Don't risk damage to tube cleaners and hose

Kinking tube cleaner hose to shut off air is poor practice at any time, especially now, when hose is a critical material. Besides ruining the hose, small hose particles may peel off and clog the motor.

Why risk damage to tube cleaners and hose by kinking the hose to control the air. A Roto Operating Air Valve, attached to the tube cleaner motor, enables the operator to control the air safely, entirely by himself. This inexpensive valve speeds up tube cleaning and releases a helper for other work. Our complete line of modern, efficient tube cleaners will meet practically every requirement. Write.

The ROTO Company
145 Sussex Ave., Newark, N. J.

A DIVISION OF ELLIOTT COMPANY

suitable agent when employed in quantities of 2 to 10 pounds per million cubic feet of gas.

U.S.P. 2,293,901. Activated Adsorbent and Its Treatment. A. J. L. Hutchinson to Fluor Corporation, Ltd.

Hydrocarbon gases such as natural gas are dehydrated by contacting the gas with porous adsorptive material capable of acquiring combined water from the gas, such as hydrates of alumina or silica. The material is provided with a protecting coating which prevents access to pore surfaces of the material of poisoning constituents of the gas, such as polymers, while permitting ready passage of moisture. Organic substances like gelatin, soaps, starch and glycogen provide desirable coatings.

Chemical Treatment of Natural Gas and Its Constituents

U.S.P. 2,213,444. Cyclic Process for the Production of Nitroparaffins. K. Johnson to Commercial Solvents Corporation.

A cyclic process for the nitration of lower alkanes in which the nitrating agent is nitric acid vapor or nitrogen dioxide, and in which unreacted lower alkane in the gaseous reaction products is recovered and recycled, involves removing lower nitro alkanes from the gaseous mixture comprising lower nitroalkanes, aldehydes and ketones resulting from the action of the nitrating agents on lower alkanes and subjecting the remaining gases to contact with a mineral-acid salt of hydroxylamine which is capable of absorbing aldehydes and ketones.

U.S.P. 2,258,511. Method of Producing Hydrogenated Liquid Hydrocarbon Products. R. Lepestre to Applied Chemicals, Inc.

Motor fuels and lubricating oils are obtained from natural gas by introducing natural gas and superheated steam under a pressure of more than 5000 pounds and at a temperature of 1000-1100° F., into a chamber and contacting the heated mixture with a catalyst consisting of an oxide of an iron group metal.

U.S.P. 2,270,779. Process of Oxidizing A Hydrocarbon. E. Berl to Berl Chemical Corporation.

An exothermically oxidizable hydrocarbon such as methane is partially oxidized (to formaldehyde) in the vapor phase, using air in the presence of an anti-knock agent (tetraethyl lead, iron pentacarbonyl, iodine), constituting from 0.005 to 0.5 percent of the total volume of the reactants and of a metal oxidation catalyst such as finely divided iron oxide.

U.S.P. 2,280,928. Chlorination of Methane. P. F. Pie, Jr., to Darco Corporation. C.A. 36, 5484.

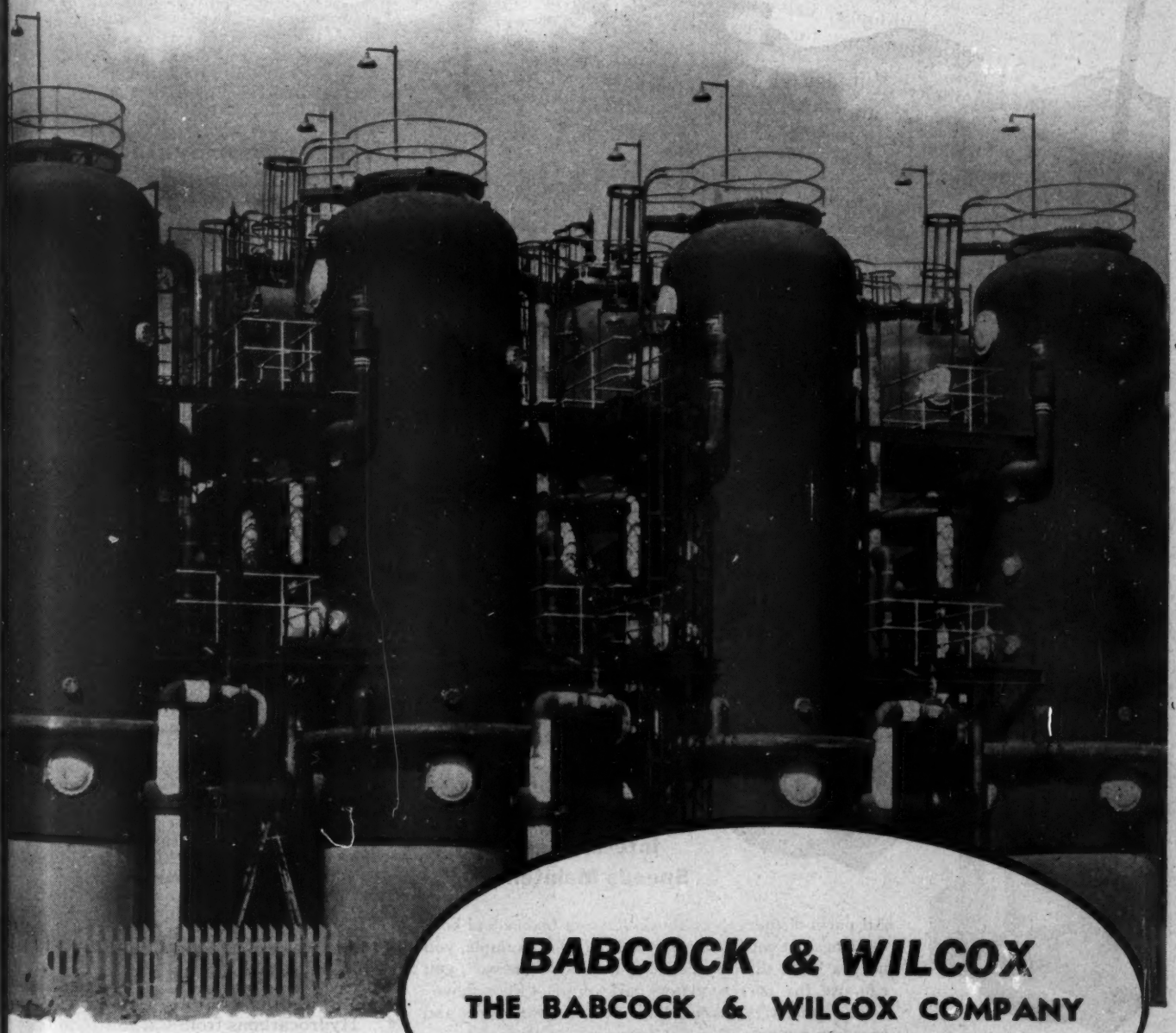
A mixture of methane and chloride is passed through a contact mass containing a catalyst for the chlorination reaction of relatively low heat conductivity such as activated carbon, and a diluent such as graphite, of relatively high heat conductivity, the gases, in their passage through the contact mass, coming into contact with portions of the mass having progressively increasing catalytic activity by use of a progressively increasing proportion of cata-

Grouped in dozens, the giant pressure vessels shown here play an important part in producing an annual output of 80,000 tons of butadiene.

They were built and supplied as part of a construction miracle which telescoped a ten years' job into two. Backing them is B&W's first-hand knowledge of process equipment requirements—a knowledge based on experience in making pressure vessels for toluene and high octane gasoline as well as for butadiene production . . . in making catalyst cases . . . separately fired high-temperature and high-pressure superheaters for butadiene . . . alloy furnace castings for various processes . . . fired and waste-heat boilers for butadiene . . . and other process equipment needed to produce ingredients of Victory.

This experience, coupled with unequalled fabrication facilities was the reason for the selection of B&W to construct heavy process equipment for another headline-making plant that is creating synthetic rubber history.

The B&W engineering personnel are always available for consultation on any of your process equipment requirements. Feel free to call on them.



BABCOCK & WILCOX

THE BABCOCK & WILCOX COMPANY

85 LIBERTY STREET, NEW YORK 6, N. Y.

INTERCHANGEABILITY Speeds Maintenance

THE wide interchangeability of parts designed into "Renewo" and "Ferrenewo" valves has long proved a boon to maintenance men in making their job easier.

Since valves control the very life lines of productive processes—steam, air, water, oil, gas and other fluids —it just follows that every precaution be taken to insure their proper functioning.

Regular checking and inspection, and prompt servicing when necessary, will be repaid in more efficient performance and longer valve life, and may well prevent possible shut-down for more costly repairs later.

The simplicity of design of "Renewo" and "Ferrenewo" valves, with interchangeable parts, makes it easy to keep them in good operating condition, with minimum expenditure for maintenance.

Use the complete facilities of Lunkenheimer distributors.

ESTABLISHED 1862
THE LUNKENHEIMER CO.
"QUALITY"
CINCINNATI 14, OHIO, U. S. A.
NEW YORK 13 CHICAGO 6
BOSTON 10 PHILADELPHIA 7
EXPORT DEPT. 318-322 HUDSON ST., NEW YORK 13, N. Y.

Here's how Interchangeability Speeds Maintenance

All parts of the valves above (except bodies and bonnet rings) fit each other perfectly. If, for example, you need a stem, disc or seat ring for the "Renewo", you can use the corresponding part of the "Ferrenewo" —*it is exactly the same.* This means fewer parts and speedier repairs.

LUNKENHEIMER VALVES

lyst and a progressively decreasing proportion of diluent.

U.S.P. 2,291,345. Hydrocarbon Nitration. O. W. Rideout to Hercules Powder Company.

Methane and nitric acid vapors are contacted for 1 second at 375° or for 0.005 seconds at 550° to produce nitromethane. In addition to 6-14 percent of nitric acid vapor and 35 percent or less of methane, an inert gas acting as a diluent should be present in the reaction zone.

U.S.P. 2,322,989. Process of Making Carbon Black and Mixtures of Carbon Monoxide from Hydrocarbon Gases. W. D. Wilcox to Oil and Gas Research, Inc.

A hydrocarbon gas to which has been added less than one half its volume of CO_2 is dissociated in a dissociation chamber at 2800-3000° F. The resulting gas mixture and the carbon particles not retained within the chamber are separated. Carbon dioxide in a volume which together with the amount of CO_2 previously used will total one half of the volume of hydrocarbon gas is then admitted to the chamber and reacts with the carbon to form carbon monoxide which is added to the gas mixture.

Hydrocarbon Synthesis from Carbon Monoxide and Hydrogen

U.S.P. 2,257,074. Manufacture of High Antiknock Hydrocarbons. A. R. Goldsby to The Texas Company.

Carbon monoxide and hydrogen are catalytically converted to a hydrocarbon mixture rich in olefins and part of the olefins are then contacted with isobutane in an alkylation zone.

U.S.P. 2,257,293. Manufacture of Hydrocarbons. H. Dreyfus.

Carbon monoxide and steam are passed over a catalytic mass adapted to produce CO_2 and H_2 from the mixture and to catalyze the reduction of carbon monoxide with hydrogen. First contact of the gas mixture with the catalyst occurs at 400-500° C. and while the steam content is maintained, the mixture is then contacted with the catalyst at 150-250° C. Metallic catalysts like nickel and cobalt are efficient for the reaction.

U.S.P. 2,257,457. Production of Aliphatic Hydrocarbons. F. Fischer and H. Pichler to Hydrocarbon Synthesis Corporation.

An iron catalyst used for the conversion of carbon monoxide and hydrogen to aliphatic solid, liquid or readily liquefiable hydrocarbons under an operating pressure of 2 to 200 atmospheres and at temperatures of 220-320° C. is activated by a preliminary treatment, in the course of which a mixture of CO and H is passed over the catalyst at a temperature of about 240° C. and under much lower pressure than the operating pressure subsequently employed.

U.S.P. 2,261,184. Process of Producing Hydrocarbons from Carbon Monoxide and Hydrogen. O. Roelen and W. Feist to Hydrocarbons Synthesis Corporation.

Catalysts such as cobalt, nickel or iron for the hydrocarbon synthesis from carbon monoxide and hydrogen are pre-

Monel wire cloth screens as used in vent check valves. Backing screen is 4-mesh, 0.047 inch diameter wire; fine screen 40-mesh, 0.0095 inch diameter wire. Made from Monel wire cloth produced by Newark Wire Cloth Company, Newark, N. J.

Monel wire cloth in vent check valves still good after 10 years' service

What can be accomplished by simple, practical design coupled with use of the right metal is well illustrated by these inverted vent check valves.

The diagram shows their uncomplicated, fool-proof construction. Note that the valves are equipped with hollow floats and seat rings of Monel, and safety screens of Monel wire cloth.

Aboard the M.S. "City of New York," the Monel wire cloth in these check valves has given satisfactory service for 10 years. Here are the reasons:

1 **Monel wire cloth is exceptionally strong, tough and hard.**

2 **It is immune to rust, and remarkably resistant to the corrosive action of sea air and salt water.**

3 **Its surfaces remain smooth, thus assuring freedom from clogging.**

Among corrosion-resisting wire cloths of comparable high strength, Monel wire cloth is *lowest in cost.* Today it is produced by prominent weavers in all commercial weaves, meshes and widths for essential war and maintenance needs. Tomorrow cloth made from Monel, Nickel and Inconel will be available for peacetime use.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

Inverted vent check valves in use aboard M.S. "City of New York."

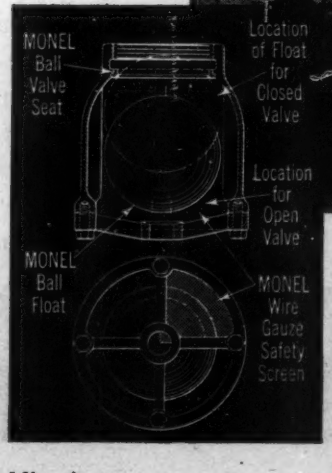

MONEL Ball Valve Seat
Location of Float for Closed Valve
Location for Open Valve
MONEL Ball Float
MONEL Wire Gauze Safety Screen

Diagram shows simple, positive action: A Monel ball float rests on a Monel screen. Air can freely enter or leave the vent pipe until the valve is submerged . . . when the float rises and makes a perfect seal with the ball valve seat. Use of fine mesh wire also prevents flame from igniting interior gases.

WeldOlets are available in three types—with Welding Outlet, Threaded Outlet (illustrated at right) and Socket Outlet. Stock fittings are drop forged steel. Also available in Monel, Everdur, Toncan Iron, Wrought Iron, etc.

Here's the simple way to install branch pipe outlets

● On this piping installation the three branch pipe outlets were installed quickly and easily by the WeldOlet method. The elimination of any templates or the need for any cutting, forming or fitting, speeded and simplified the installation.

These drop forged fittings reinforce the junction so that the original strength of the main pipe is maintained. In addition, the extra large funnel-shaped opening, in the fittings where they join the pipe, cuts pressure loss and reduces turbulence and friction. The WeldOlet method is speedy and low in cost for both size to size or reducing branch pipe outlets. Size to size and reducing sizes are available from ¼" to 12". For complete information write for Branch Pipe Outlet Catalog WT31.

Forged Fittings Division

Bonney Forge & Tool Works · 346 Green St. · Allentown, Pa.

WELDOLETS
TRADE MARK REG. U.S. PAT. OFF. PAT. IN U.S. & FOREIGN COUNTRIES
WELDING OUTLET - THREADED OUTLET - SOCKET OUTLET
For Welded Branch Pipe Outlets

cipitated from their salt solutions with alkaline reacting agents and applied to pretreated carrier substances such as kieselguhr which have been heated to render them insoluble, so as to prevent soluble components from entering the solution from which precipitation is effected.

U.S.P. 2,266,161. Process for Reacting Hydrogen and Oxides of Carbon. D. L. Campbell and F. T. Barr to Standard Oil Development Company. C.A. 36, 2272.

Synthesis gases comprising hydrogen and oxides of carbon and containing therein a powdered catalyst are passed through a reaction zone, under temperature and pressure conditions adapted to cause the oxides of carbon and hydrogen to react, removing exothermic heat of reaction immediately as it is formed along the path of the flowing gases in the reaction zone through the walls of the reaction zone by circulating a cooling medium within the walls of the reaction zone.

U.S.P. 2,271,259. Process for Synthesizing Hydrocarbons. W. Herbert to American Lurgi Company.

A process is employed for the conversion of carbon monoxide and hydrogen into hydrocarbons with catalysts adapted to form benzine oil and paraffin under atmospheric pressure, the catalysts being arranged in a contact chamber adapted to maintain a desired reaction temperature therein which involves maintaining a temperature above 150° but below the temperature required for the exclusive formation of methane with the catalysts, maintaining a velocity of gas flow in contact with the catalysts above one normal liter per hour per gram of hydrogenating metal in the catalysts and adjusting the pressure of the gas to a pressure above atmospheric and sufficient that the time the gases remain in contact with the catalysts is more than 45 seconds. Such catalysts as cobalt, thorium oxide and kieselguhr may be used.

U.S.P. 2,274,639. Process for the Production of Hydrocarbons. A. Scheuermann, K. Meisenheimer and A. Kotzschmar to Standard Catalytic Company.

Carbon monoxide and hydrogen are converted to hydrocarbons in the presence of cobalt-containing catalysts in the preparation of which a reducible cobalt compound is gradually precipitated at room temperature from a solution of a cobalt salt over a period of more than three hours. Carbon monoxide and hydrogen are passed over the catalyst at 160-250° C. and, when producing the preferred product of low-boiling liquid hydrocarbons, up to 2 atmospheres, when producing the preferred product of solid hydrocarbons 5-50 atmospheres of pressure are employed.

U.S.P. 2,276,274. Method of Synthesizing Hydrocarbons. P. C. Keith, Jr. to The M. W. Kellogg Company.

A method employing an excess of carbon monoxide with respect to hydrogen, involves heating a mixture of carbon monoxide and hydrogen to a synthesizing temperature, bringing the heated mixture into contact with a hydrogenation catalyst in a synthesis zone, separating unreacted gases to obtain a fraction predominating in carbon monoxide and admixing at least a part of this fraction with the carbon monoxide

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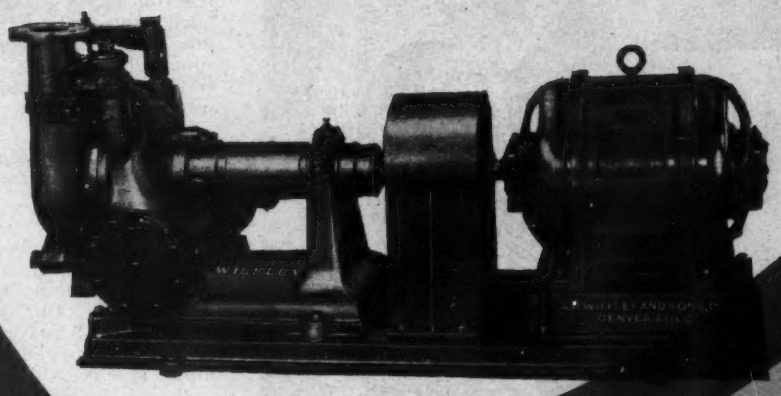

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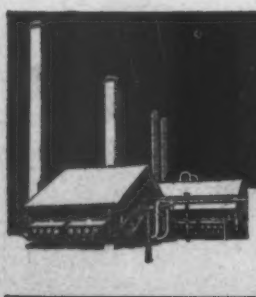

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and hydrogen being fed to the synthesis zone to maintain the desired excess of carbon monoxide over hydrogen during the synthesis.

U.S.P. 2,279,052. Production of Hydrocarbons. W. Michael and E. Planth to Standard Catalytic Company.

A process for the synthesis of hydrocarbons with more than one C atom per mol and contingently minor amounts of from liquid to solid oxygen containing derivatives such as alcohols is described, which involves returning to the reaction space gases which have already been subjected to the reaction, the volume of the gases returned per unit of time being at least 20 times that of the fresh gas introduced in the same unit of time.

U.S.P. 2,286,814. Manufacture of Motor Fuel. L. C. Kemp to The Texas Company.

A mixture of carbon monoxide and hydrogen is converted into synthetic hydrocarbons in the presence of a catalyst consisting essentially of cobalt, kieselguhr and small amounts of thorium and magnesium oxides at a temperature of about 330-392° F. and under low pressure. The gaseous hydrocarbons obtained are then subjected to isomerization and alkylation processes.

U.S.P. 2,287,092. Synthesis of Hydrocarbons. F. Duftschmid, E. Linckh and F. Winkler to Standard Catalytic Company.

A process for the catalytic conversion of carbon monoxide and hydrogen into hydrocarbons containing more than one C atom per mol while contained in a hydrocarbon oil is claimed, which comprises passing the said hydrocarbon oil along the catalyst chamber in indirect heat-exchange relation with the reaction participants introduced into and passing through the catalyst chamber, and thereupon passing the said oil through the catalyst chamber in the same direction as the reaction participants.

U.S.P. 2,287,891. Production of Hydrocarbons and Their Derivatives from Mixtures of Hydrogen and Oxides of Carbon. E. Linckh to Standard Catalytic Company.

Mixtures of carbon monoxide and hydrogen are converted into hydrocarbons containing more than one C atom per mol by contacting them at 150-500° C. and atmospheric or elevated pressure with a catalyst obtained by treating fused ferrosoferric oxide with a reducing gas at 300-850° C. The ferrosoferric oxide may contain a substance selected from the group consisting of compounds of titanium and silicon.

U.S.P. 2,296,405. Production of Hydrocarbons. A. Scheuermann and E. Marecek to The Alien Property Custodian.

Good yields of solid and liquid hydrocarbon products are obtained in the conversion of carbon monoxide and hydrogen when employing catalysts containing iron and nickel compounds which have been prepared by slowly precipitating reducible iron and nickel compounds from a solution of salts of said metals at a temperature of 40° C. or below and preferably at a temperature of below 30° C., while maintaining a pH value of not less than 8 in the solution during precipitation. The precipitation

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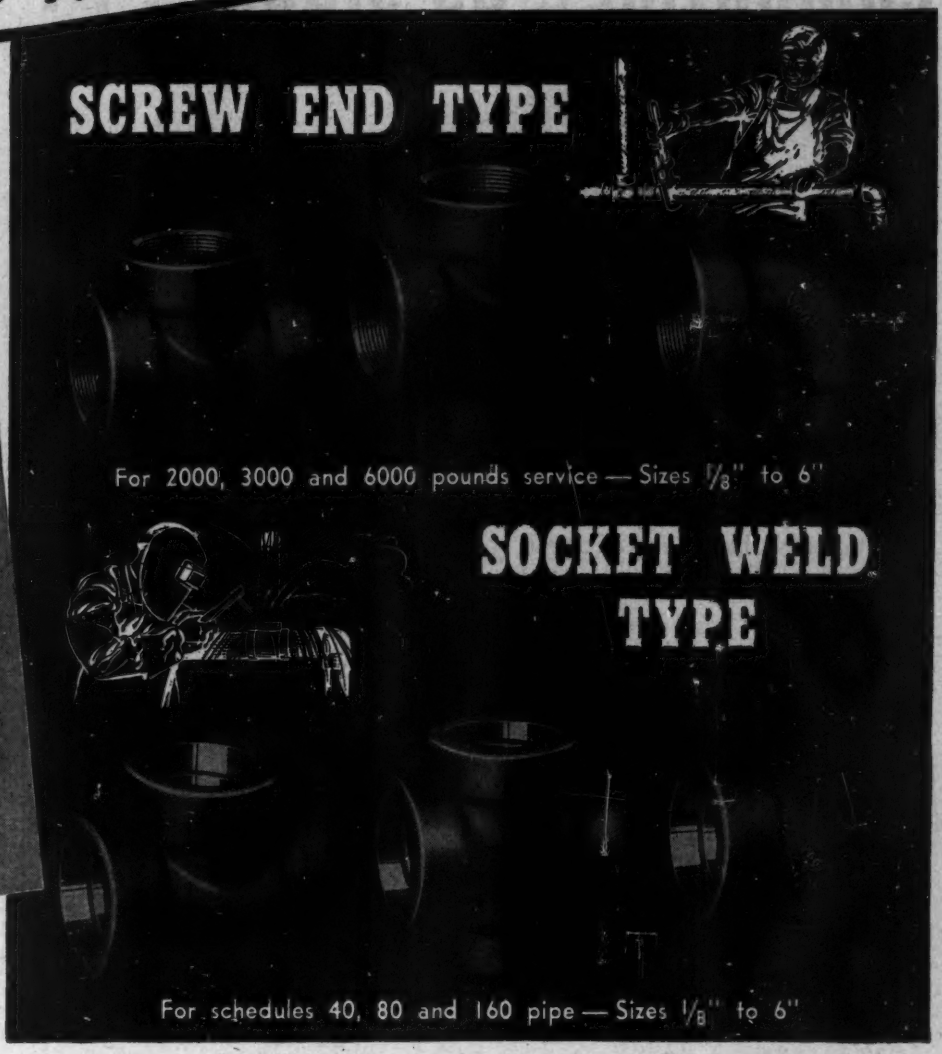
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U.S.P. 2,318,602. Synthesis of Hydrocarbons. F. Duftschmid, E. Linckh and F. Winkler to Standard Catalytic Company.

Carbon monoxide and hydrogen are catalytically converted into hydrocarbons with more than one C atom per mol in the presence of fixed catalysts by a process which comprises continuously circulating through the reaction space, co-currently with the reaction gas, a liquid medium preheated to about the desired reaction temperature, injecting into the reaction zone at spaced points along the passage of the said gases additional regulated amounts of the same liquid medium at temperatures substantially below said reaction temperature so as to maintain the temperature throughout the reaction space within the resired limits and employing as the liquid medium an oil obtained by a previous conversion. This oil should contain a considerable amount of constituents which are gaseous or vaporous under the reaction conditions.

U.S.P. 2,318,626. Production of Products Rich in Unsaturated Hydrocarbons. M. Pier and E. Donath to The Alien Property Custodian.

Products rich in unsaturated hydrocarbons can be obtained from the catalytic conversion of carbon monoxide and hydrogen in the gas phase at atmospheric or slightly increased pressure, by charging gas mixtures which contain less than two parts by volume of hydrogen for each part by volume of carbon monoxide and adding further hydrogen in the course of the reaction. The total amount of hydrogen used should correspond to two parts by volume of hydrogen for each part by volume of carbon monoxide.

More Pressure Tank Cars Provided by New Program

Inauguration of a $3,500,000 program to add 1000 cars to the present total of 3282 pressure-type tank cars, to meet increasing demand for various petroleum products and particularly an urgent need for more equipment to transport liquefied petroleum gases, was announced June 21 by the Office of Defense Transportation. The War Department would build 400 new high-pressure type cars and convert 600 standard tank cars of 10,000-gallon capacity to low-pressure type equipment.

There is growing need for equipment because of the invasion of Europe, and deliveries are scheduled to start next October and be completed before December 31.

"The War and Navy Departments desperately need every gallon of fighting-grade aviation gasoline that can possibly be produced," ODT Director J. Monroe Johnson said in announcing the program. "The Office of the Rubber Director and the Rubber Reserve Company also desire increased quantities of butylene feed stocks for the manufacture of synthetic rubber.

"In addition to supplying all transportation requirements for 100-octane aviation gasoline and synthetic rubber feed stocks, the demand for cars to move liquefied petroleum gases must also be met. Many war plants, ship yards, war housing projects, essential manufacturing plants, Army camps, home heating plants, etc., are dependent upon this material."

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

The Variation of the Viscosity of Gases and Vapors with Temperature. W. LICHT, JR., AND D. G. STECHERT. *J. Phys. Chem.* **48** (1944) pp. 23-47.

Experimental data are given for the variation in the coefficient of viscosity with temperature for 24 gases and vapors at atmospheric pressure. The authors find that except for hydrogen and helium, Sutherland's equation reproduces the data with an average error of less than 1 percent over the range of measurement. Trautz's equation fits for hydrogen and helium as well as for the other gases, with an error of approximately 1 percent. Other equations are less satisfactory or more difficult to use. Methods for the evaluation of the constants in the various 2-constant equations are developed and tables of constants are given. Only 2 points on the viscosity-temperature curve are necessary for the calculation of the entire curve. A general viscosity-temperature equation is proposed for estimating the viscosity when no experimental data are available. The data required are critical temperature, critical pressure, molecular weight of the gas, and in general the experimental results are reproduced within 2 to 10 percent. A nomograph is given for the evaluation of viscosity based on this equation.

Thermodynamic Properties of Ethylene. R. YORK AND E. F. WHITE. *Trans. Amer. Inst. Chem. Engr.* **40** (1944) pp. 227-250.

The increasing use of lighter hydrocarbons in the process industries justifies the evaluation of their basic thermodynamic properties, enthalpy and entropy. The literature covering the physical properties of ethylene is reviewed in a critical manner and the best values of boiling point, critical constant, vapor pressure, volumes of saturated liquid and saturated vapor, enthalpy of vaporization, heat capacity of superheated vapor, P-V-T relationships of the superheated vapor, normal density, enthalpy of superheated vapor and entropy of superheated vapor are chosen. In order to present the properties in a useful chart it was decided to construct a pressure-enthalpy diagram with lines of constant volume, temperature, and entropy. A chart of the pressure-enthalpy relationship for ethylene is included. The physical data are presented in some detail in tabular form. A bibliography of 28 references is included.

Chemical Compositions And Reactions

n-Nonatriacontane. E. STENHAGEN AND B. TAGTSTROM. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 845-6.

During some attempts to mono-alkylate acetone dicarboxylic ester (diethyl B-ketoglutarate) with octadecyl iodide, the dialkylated ester was also formed as a by-product, and this, after hydrolysis and decarboxylation yielded nonatriacontanone-20. Reduction of this latter compound gave n-nonatriacontane. An alkyl halide having n carbon atoms thus yields a hydrocarbon with $2n + 3$ carbon atoms. After three crystallizations from benzene the melting point of the hydrocarbon was 80.0-80.2° C. The carbon hydrogen analysis agrees very closely with the formula $C_{39}H_{80}$.

The Thermal Decomposition of Substituted Cyclohexenes. F. O. RICE AND MARY T. MURPHY. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 765-7.

When cyclohexene is heated above its decomposition point, at low pressures and for a time sufficiently short that only a small part is decomposed, it undergoes a simple dissociation into smaller molecules. The principle governing reactions of this type is that that reaction is favored that involves as little motion of the atoms as possible in passing from the old to the new configuration, and further, that that reaction will be favored that involves least change of the electronic configuration of the reacting system. In the case of cyclohexene almost a theoretical yield of butadiene and ethylene is formed, as would be predicted. The thermal decomposition of a number of substituted cyclohexenes was studied in the expectation that they would follow the pattern of the cyclohexene decomposition and yield substituted butadiene and ethylene. This was found to be true for 1-methyl, 3-vinyl and 1-phenyl cyclohexene. In the case of ethylcyclohexene, the expected ethylbutadiene was not detected. Dipentene gave, as was to be expected, a high yield of isoprene. On the other hand, 3-p-menthene gave a high yield of propylene but no isopropylbutadiene could be found. The results of the experimental work are presented in tabular form, and the methods by which the data were obtained are described.

Reaction of Benzene with Butadiene in the Presence of Sulfuric Acid and Hydrogen Fluoride Catalysts. V. N. IPATIEFF, H. PINES AND R. E. SCHAAD. *Jour. Amer. Chem Soc.* **66** (1944) pp. 816-17.

The reaction between benzene and butadiene in the presence of sulfuric acid and of hydrogen fluoride as catalyst was studied in the hope that products might be obtained that would be valuable in synthetic work. To favor the reaction with benzene and to decrease polymerization of butadiene, a large excess of benzene was used in the reaction mixture. The hydrocarbon of lowest boiling point obtained was 1,2-diphenylbutane, formed by the reaction of two molecules of benzene with one of butadiene. The laboratory procedure used in the work is described in some detail.

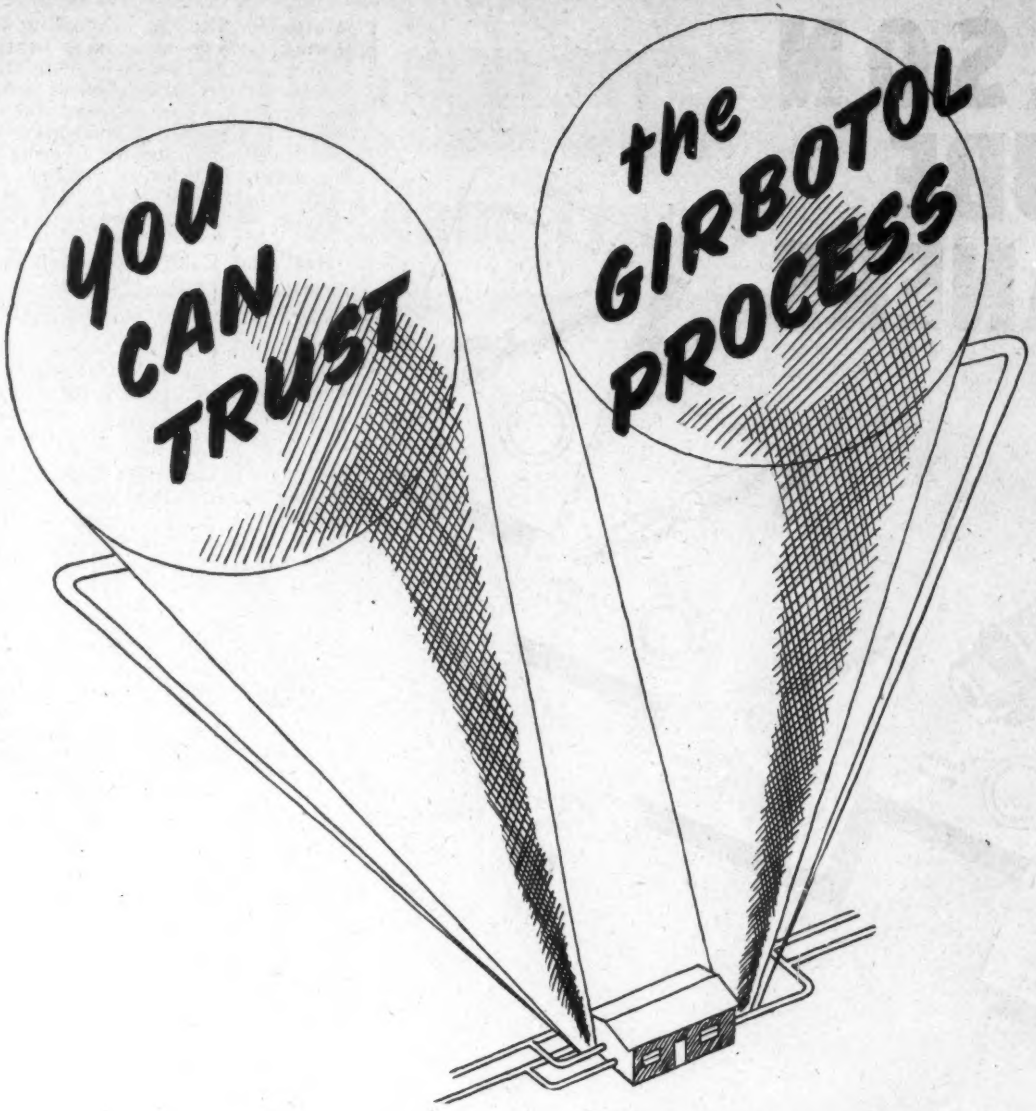
Manufacture: Processes and Plant

Heat Transfer. Conduction, Radiation and Convection. H. J. STOEVER. *Chem. & Met. Engr.* **51** (1944) pp. 98-107.

The author reviews the processes of transmission of heat by conduction, radiation and convection, and considers film coefficients in relation to overall coefficients of heat transmission. Tables and nomographs are presented, by means of which film coefficients for a number of fluids under various conditions can be quickly determined. Twenty-four different cases are considered. The application of dimensional analysis to the calculation of the film coefficient is briefly discussed.

Equipment for Heat Transfer and Heat Application. M. W. SCHWARZ. *Chem. & Met. Engr.* **51** (1944) pp. 120-131.

Almost every processing operation involves some form of heat transfer, and the types of equipment required are most varied. The author considers ap-



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Heat and Cold, Production and Application for Processes. W. J. SHORE. *Chem. & Met. Engr.* **51** (1944) pp. 109-117.

The author divides the ranges of temperature in which heat is transferred into the refrigeration range, from room temperature down to the melting point of helium, the range of organic processing, from room temperature up to perhaps 900° F., and the range of inorganic processing, from 600-900° F. up to the highest temperatures attainable. Heat abstraction or production means for these temperature ranges are briefly discussed. Flame temperature, flame radiation, combustion space, and volume are considered in relation to furnace design. Application of electric heat is briefly considered. Cooling processes, including evaporative cooling and refrigeration, are briefly discussed. Types of heat transfer equipment, including those for submerged combustion, are briefly reviewed.

Unsteady State Heat Transfer to Liquids in Tanks. R. E. CHADDOCK AND M. T. SANDERS. *Trans. Amer. Inst. Chem. Engr.* **40** (1944) pp. 203-210.

The authors give exact derivations of the equations that can be used in several types of unsteady state heat transfer problems. Typical applications are the heating or cooling of batches of liquids in agitated tanks equipped with a coil surface, or in a tank combined with an external heat exchanger. The modification of the equation for the case in which heat of reaction must be removed, as well as sensible heat, is indicated.

Annular Heat Transfer Coefficients for Turbulent Flow. E. L. MCMILLEN AND R. E. LARSON. *Trans. Amer. Inst. Chem. Engr.* **40** (1944) pp. 177-202.

Heat transfer in a double-pipe exchanger of four passes having different annular spaces was studied using water as the heating or cooling medium. The usual plot of $1/U_i$ vs. $1/G^{0.8}$ to determine the constant total resistance due to pipe wall and film of the heating fluid was found to be more accurate if the effect of variation in film viscosity of the annular fluid was included. Annular film coefficients can thus be determined from measurement of terminal temperatures and flow rates of both fluids at a series of increasing annular flow rates. The Colburn equation $j = (h_i/CG)(C\mu/k)f^{2/3}$ provides a better correlation of the annular heating and cooling data for narrow annular spaces than does the Davis equation. Use of the Colburn "j" function may eliminate the need for the D2/D1 term included in previous annular film coefficient equations. The data taken in the course of the work are presented in detail in tabular and graphical form. The proper numerical coefficients for annular film coefficient equations of the Colburn and Davis types are given, which are applicable at Reynolds numbers (D_1G/μ) above 10,000. At lower Reynolds numbers film coefficients are

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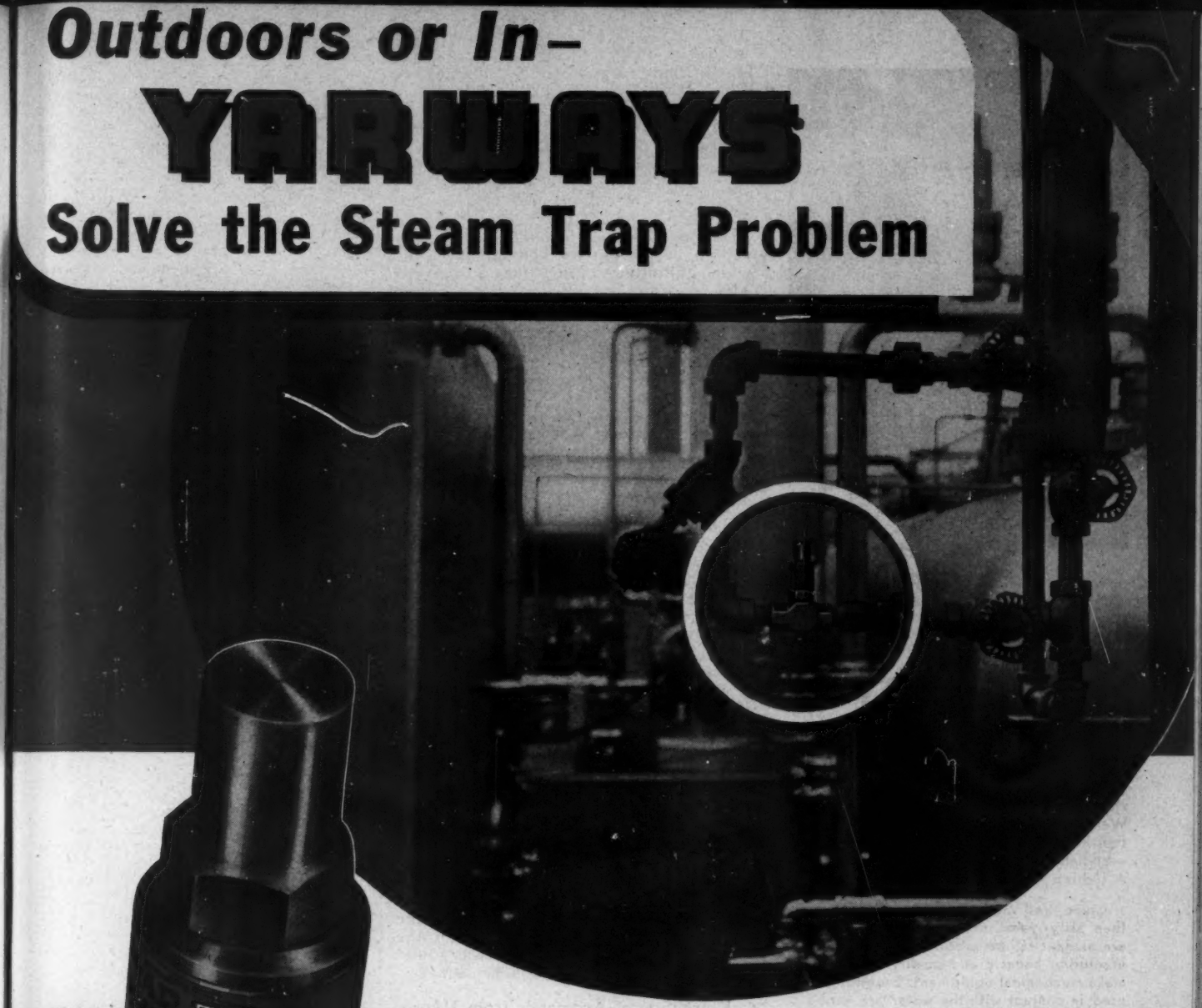

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higher than correspond to these equations.

Film Coefficients for the Condensation of Vapors. R. F. BENENATI AND D. F. OTHMER. *Chem. & Met. Engr.* **51** (1944) pp. 107-9.

A parrallel-scale nomograph for determining film coefficients of condensing vapors is presented. The equation on which the nomograph is based is given. The equation fits physical data within their probable errors, and because of the large number of vapors considered the equation is regarded as general and can be used with reasonable probability of accuracy for vapors where experimental data are not known.

Countercurrent Absorption in Non-Aqueous Systems. W. F. GROSS AND C. W. SIMMONS. *Trans. Amer. Inst. Chem. Engr.* **40** (1944) pp. 121-141.

The absorption of the vapors of benzene, trichlorethylene, and chloroform by kerosene was studied in a 1-foot diameter column packed with 1-inch Berl saddles. According to the two-film theory of gas absorption developed by Whitman and others, the over-all absorption coefficient can be related to the gas rate by the empirical relation

$$K_g a = aG^{\lambda}$$

for cases of absorption of a vapor that is very soluble in the solvent. $K_g a$ is the over-all coefficient expressed as (lb. moles)/(hr.)(cu. ft.) (atm.) and G is the gas rate as (lb.)/(hr.)(sq. ft.). The absorption of the three vapors was studied at gas rates up to 80 (lb.)/(hr.)(sq. ft.), and at liquid rates in the range 1000 to 3000 (lb.)(rh.)(sq. ft.). It was shown that the above empirical relationship is valid, and that the liquid film resistance is apparently negligible within the flow rate limits. The constants a and λ in the equation have been determined for the three systems studied, and it was found that the value of λ approaches unity.

Extraction of Aromatics from Hydrocarbon Mixtures. A. S. SMITH AND J. E. FUNK. *Trans. Amer. Inst. Chem. Engr.* **40** (1944) pp. 211-225.

The authors investigated the separation of aromatic hydrocarbons from paraffins, naphthenes and olefins by extraction with a selective solvent. Single solvents are unsuitable for the separation of pure components. To accomplish complete separation a solvent must be partially miscible with the components to be separated at the operating temperature. However, miscibility cannot be too limited or the solvent requirement becomes prohibitive. Solvent solutions used by the authors were methanol-ethylene glycol and dipropylene glycol-ethylene glycol. A solubility diagram is given for ternary systems composed of methyl alcohol, ethylene glycol and various hydrocarbons as the third component. Several typical equilibrium diagrams are presented. The extraction column used in the work is described, as well as its method of operation. The recovery of the solvent is briefly considered. Extraction of aromatics from gasoline is described and the distribution of the various hydrocarbon components between the raffinate and the extract is shown by diagram. The extraction of aromatics can be applied in the production of high solvency naphthas, or aromatic-free kerosenes and Diesel fuels, and in the recovery of

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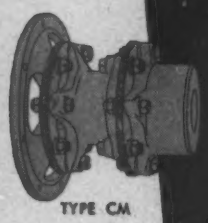

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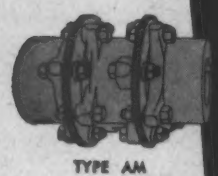

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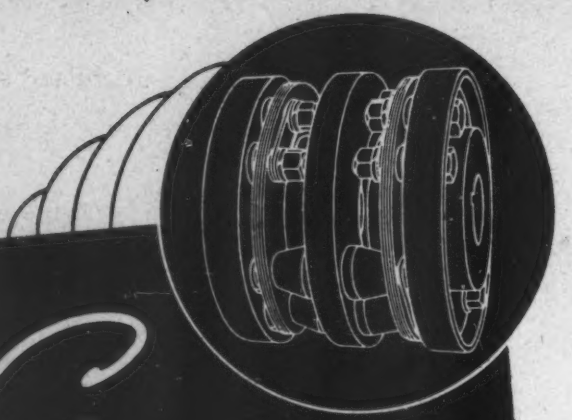

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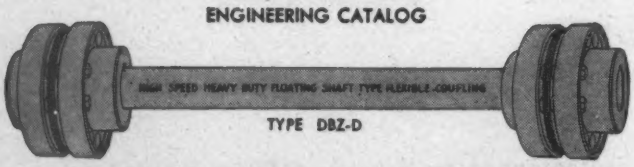

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aromatics from gasoline fractions. Solvents used in the work are selective, readily available, cheap, stable, noncorrosive, and non-reactive with the hydrocarbons. The ratio of solvents in the particular solvent solution used can be varied within limits to suit the particular feed material and the extraction to be made.

Some Aspects of the Chemistry of Antioxidants. F. BERGEL. *Chem. & Ind.* 14 (1944) pp. 127-8.

From the organic chemist's point of view there is little difference between antioxidants useful for the food industry and those incorporated in petroleum, rubber, high polymers, or paint. In most cases it is a question of protection of unsaturated substances against the reaction with oxygen and peroxide. The literature of the manner in which inhibitors work is briefly reviewed. The most important group of antioxidants includes compounds rich in hydroxy groups, especially of phenolic or enolic character. The quinols, polyphenols, dienols, ω-hydroxyacetophenomes and nitrogen-containing compounds are included and discussed.

The Diffusion of Gaseous Hydrocarbons Through Rubber Membranes. L. LONG. *J. Chem. Ed.* 21 (1944) pp. 139-41.

The diffusion of hydrocarbons through rubber or neoprene membranes is represented by the equation used for the diffusion of gases through solids. The author views it as probable that hydrocarbon mixtures can be separated by diffusion through properly selected diaphragms.

Products: Properties And Utilization

Polythene. J. C. SWALLOW. *Endeavour* 3 (1944) pp. 26-31.

The high molecular weight polymers of ethylene are now produced in a new series known as polythene. They are made by polymerizing ethylene under extremely high pressure. The polythene is the longest unbranched straight-chain hydrocarbon produced by synthetic methods. It is the simplest synthetic thermoplastic and consists of long methylene chains of 1000 units or more. Its structure results in desirable electrical properties such as low dielectric constant, low power loss, and small water absorption, together with good mechanical properties. Experimental work done prior to its production covered the range in pressure from 1000 to 12,000 atmospheres. Heat is liberated upon polymerization, and special equipment was required in order to avoid explosive decomposition. X-ray examination of the polymer indicates crystalline structure of orthorhombic symmetry. The best classification of the polythenes is based on measurement of the liquid viscosity of the molten polymer at 190° C. in a specially designed viscometer. Chemical properties of the substances are those to be expected from the structure and chemical composition. Solubility in organic solvents is low at ordinary temperatures, but increases fairly rapidly between 50 and 70° C. Polythene is not affected at room temperature by strong acids or alkalis, but is affected by chlorosulfonic acid. Nitric and sulfuric acid affect the compound at 100° C., but hydrochloric acid and caustic soda do not. Ozone has less

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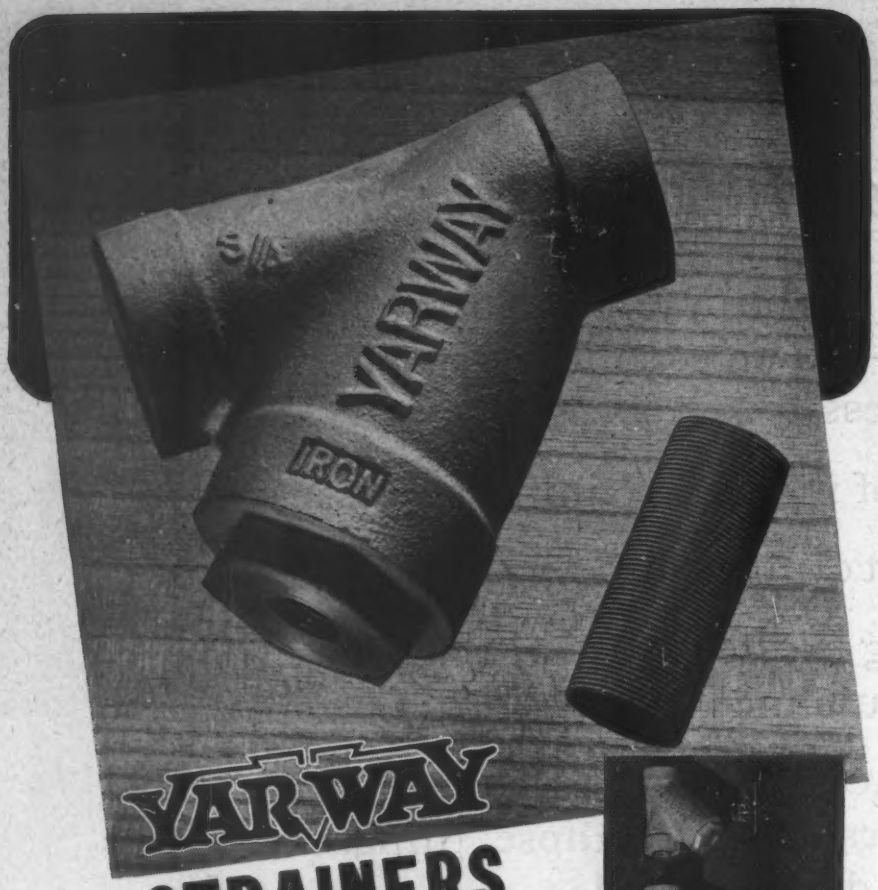

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effect on the polythenes than natural rubber. Polythene can be chlorinated, producing plastic products ranging in physical properties from rubbery to hard solids. Antioxidants effectively prevent oxidation. Heating under high vacuum does not result in changes up to about 300° C., where decomposition starts and brittle waxes, greases and oils form. The polythenes are tough, flexible, and possess high impact strength. Under tension the typical product elongates until the stress has reached a critical value of about 100 kilograms per square centimeter. The behavior of the polythene under drawing is comparable to that of rubber. The most satisfactory plasticizer for the compound is polyisobutylene of high molecular weight. The polythenes are particularly suited for electrical applications because of the high breakdown voltage and imperviousness to water. It is also a desirable material for many purposes in which chemical resistance is of importance.

Oxidation of Lubricating Oils. G. H. DENISON, JR. *Ind. & Eng. Chem.* **36** (1944) pp. 477-82.

The oxidation of lubricating oils, as well as the corrosion of bearings by lubricating oils, is the subject of an extensive investigation. A picture of lubricating oil constitution must be had before the mechanism of oxidation can be determined. Finished lubricating oils comprise many different hydrocarbons which make up from 80 to 98 percent of the oil, along with 2 to 20 percent sulphur compounds, 0.08 to 0.3 percent nitrogen compounds, and some oxygen compounds. The hydrocarbon portion of the oil is shown to comprise naphthenes in admixture with homologs of benzene and naphthalene. This hydrocarbon portion of lubricating oil is shown to possess negligible resistance to oxidation when it is freed of the natural sulphur compounds. Thus, the few percent of sulphur compounds present in a finished lubricating oil determine the oxidation characteristics. This control of stability is interpreted as resulting from the fact that the hydrocarbon fraction oxidizes at a rate controlled by the concentration of organic peroxides. The peroxides are reduced by reaction with the natural sulphur-containing compounds and are thus eliminated as promoters of oxidation. Unfortunately the oxidation of the sulphur compounds by the peroxides results in the formation of deleterious compounds. Thus the refiner is forced to a choice of the lesser of two evils. He must maintain sufficient natural sulphur compounds in his oil to prevent the development of appreciable peroxide content with consequent higher oxidation rate, yet keep the sulphur content sufficiently low so that whatever oxidation does occur will not give rise to too many deleterious compounds. The author also points out that sulphur compounds, in addition to controlling the rate of oxidation of an oil, determine the rate of corrosion of bearings. Bearing corrosion is shown to result from the reaction of peroxide with the metals of the bearings, forming metallic oxide, which compound reacts with the acidic components in the oil to form the metallic salt. In the absence of peroxide the acidic compounds cause no corrosion. This correlation between peroxide concentration and corrosion is not surprising when it is remembered that the greatest class of corrosion inhibitors are agents that will

Guessing and gazing are out when it comes to buying your flow control equipment. Because, for even the simplest operation, the valve must be of correct design to obtain maximum efficiency. This not only includes basic type, such as Globe, Angle, Gate, "Y", Check, etc., but such factors as suitable stem action, bonnet construction, working pressure and especially the materials used in the body and mountings.

The valves shown here are a few of the complete line designed by POWELL Engineering for refinery services. When made from the proper pure metals or special alloys, as recommended by our Engineers, they are especially adapted for handling Hydrogen Chloride in Isomerization Plants and Hydrofluoric Acid, Sulfuric Acid, and Sodium Hydroxide in Alkylation Plants.

And, to help you solve your individual flow control problems, POWELL Engineering is always at your service for consultation.

Fig. 1944—Stainless Steel "Y" Valve for 125 pounds W. P. Has flanged ends, with outside screw rising stem threaded through bronze yoke bushing and bolted flanged yoke bonnet. Body can be provided with cleanout pockets on special order. This type of valves provides the straightway full flow area of the Gate valve plus the throttling feature and easy regrinding and renewability of disc of the Globe valve, thereby effecting considerable savings in maintenance.

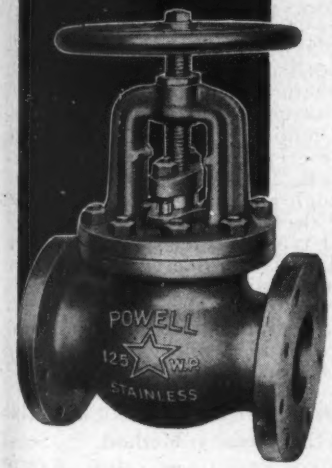

Fig. 2457—Large size Stainless Steel Globe Valve for 125 pounds W. P. Has flanged ends, outside screw rising stem threaded through bronze yoke bushing, full round bolted flanged yoke bonnet, and plug type disc. Sizes, 4" to 12", inclusive.

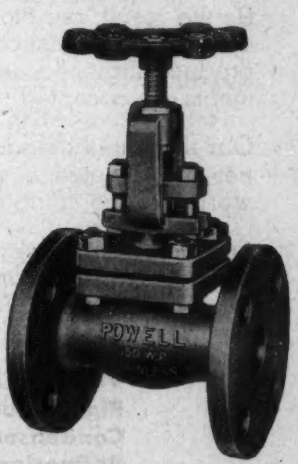

Fig. 1979—Stainless Steel Globe Valve for 150 pounds W. P. Has flanged ends, outside screw rising stem threaded through bronze yoke bushing, bolted flanged yoke bonnet, and plug type disc. Sizes, ¼" to 3", inclusive.

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reduce organic peroxides, for example, organic phosphites, arylamines, and phenolics.

Recent Developments in Colloidal Carbon. W. B. WIEGAND. *Can. Chem. & Proc. Ind.* **28** (1944) pp. 151-62.

For synthetic rubber reinforcement with carbon is even more essential than for natural rubber in order to strengthen the polymers, improve the modulus, increase tear resistance, and to aid in satisfactory curing. There are three processes for making carbon blacks: (1) cracking at hot surfaces as in the Thermatomic process, (2) free flame processes, and (3) new furnace methods, employed in the manufacture of Statex and high-modulus furnace products. Carbons of low pH value retard curing, those of high pH value accelerate it and contribute to economy in the use of organic accelerators. The electron microscope has proved useful in the study of colloidal carbon. The spherical form was found to be usual for colloidal carbon. The latex particles of synthetic rubbers vary in size from 58 to 8500 millimicrons; in general they are larger than the carbon particles, the diameters of which range from 12 to 275 millimicrons. The discrete rubber theory for natural rubber is based on the assumption that the rubber particles are larger than the carbon particles. However, the electron microscope indicates that the carbon particles may be as large or larger than the rubber particles and it is therefore probable that carbon is sometimes discrete instead of rubber. So-called "normal" carbons are floccular and they deflocculate in milling. The so-called structure carbons are able to retain their structure throughout the mixing and milling operations Acetylene black is the extreme example of structure carbon. The reticular structure results in high absorption, high modulus, and good electrical conductivity. Surface areas and typical grades of carbon are tabulated. It is considered that surface determines tensile, energy, color, tinctorial strength and absorption; pH affects curing rate, preferential absorption, organophilic tendencies, hydrolytic adsorption, and combined oxygen.

Analysis of n-Butane-Isobutane Mixtures by the Density Method. E. SOLOMON. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) p. 348.

A method for the analysis of mixtures of n-butane and isobutane is briefly described. The method is similar to that of Leighton and Heldman but is described so that other laboratories may have the benefit of the author's experience in assembling a simple and compact analytical unit. Using calibration charts the method can readily yield results accurate to ± 1 percent in about 15 to 20 minutes from the time the sample is introduced into the sample chamber and until the apparatus is ready to take the next sample. About 10 ml. of liquid is a convenient size of a sample but there is no reason why this quantity cannot be reduced.

Fluorocolorimetric Determination of Blended Oils and Oil in Oil-Water Emulsions. H. BENJAMIN. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) p. 331.

The author was called upon to determine the concentration of sulfurized cutting oils blended with straight min-

Fighting or Producing, it Means the Same... *Be Ready!*

Whether it be a warship at sea alert for enemy craft, or a vital industrial plant geared to top production, delay at a critical time is costly, often disastrous. A good skipper knows the great importance of having his ship ready at all times for the command to "Stand By!" Likewise, management is aware of costly delay caused by forced shutdown due to regular gas supply failure.

A Pritchard designed Stand-By fuel system will eliminate such a possibility. Fuel can be delivered by rail tank car or truck at any time, and stored for an emergency or critical demand.

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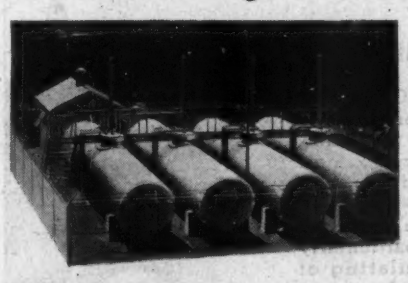

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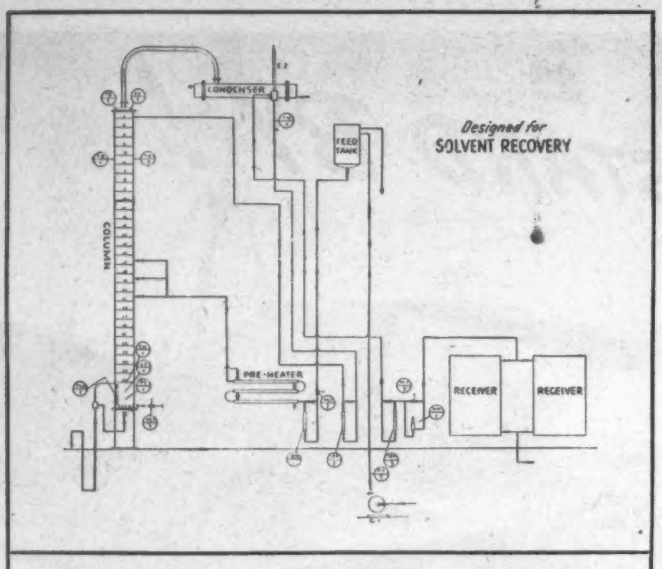

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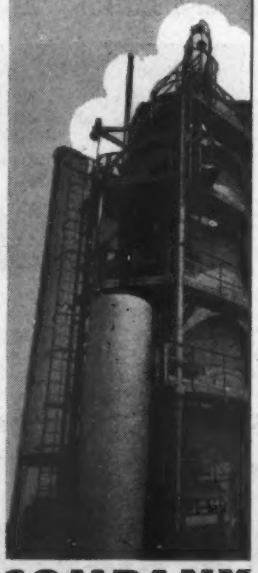

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For applications up to 1600°F. this refractory covers the full temperature range, eliminating the old fashioned method of using two blocks . . . an important feature in these days when speed is so essential.

Efficient, high temperature and moisture-resistant, Kel-Bloc is particularly recommended for the insulating of pressure vessels, heat exchangers, steam accumulators, boilers, furnaces, oil heaters, dryers, ovens, breechings, ducts.

Kel-Bloc is composed of long fibre black Rockwool, felted and bonded together to give uniform density. Due to a special method of felting, all voids are eliminated and stratification is uniform.

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eral oil used as a cutting coolant and also to determine the oil content of oil-water emulsions. The available methods were time consuming and none too accurate. In order to develop a more rapid method and improve the procedure, use was made of the phenomenon of fluorescence excited by ultraviolet rays. Determinations by this means could be made in as many minutes as the older methods took hours. They are applicable to all oils and waxes that fluoresce, and through the addition of suitable oil-soluble fluorescent dyes they can be made applicable to all oils and waxes. The method is described in some detail. Determination of the oil in oil-water emulsions could be performed by visual matching to ±0.1 percent. The procedure can also be applied to determine the efficiency of oil removal when metal parts are cleaned and washed by various methods. A trace of oil not visible to the naked eye becomes apparent when excited by ultraviolet rays.

Analytical Fractionation of Asphalts. A. J. Hoiberg and W. E. Garris, Jr. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 294-302.

Insight into the behavior of asphalts is best obtained through knowledge of the component fractions. Separation into fractions serves to characterize the asphalt. The authors describe a procedure for the solvent separation of asphalts into five fractions: hexane-insolubles, hard resins, soft resins, oils, and waxes. All of the solvents employed boil above room temperatures, so the method requires only laboratory glassware. All fractions are recoverable, which is an advantage in that they can be studied to characterize the asphalt further. The accuracy and precision of the method are discussed. Tabulations of data are included to show the averages and ranges of fractions and the properties of fractions recovered from 37 oxidized and 7 straight-run asphalts. These are used to illustrate some applications of the method in the study of asphalts. The method is regarded as suitable for products varying in consistency from road oil to highly blown products. Only a few trials have been made on cracked asphalts, but the treatment is thought to be applicable to them except for some products produced by high level cracking which, although resinous, are largely insoluble in hexane. Some other petroleum products can be examined in a similar manner, as, for example, extracts and precipitates from lubricating stocks and lubricating oils that have been in heavy-duty service.

Andrus Again President of Penn State Crude Oil Body

D. T. Andrus of Bradford, Pennsylvania was reelected president of the Penn Grade Crude Oil Association at the annual meeting in Pittsburgh. Other officers elected were A. C. Simmons, of Bradford, vice president; D. T. Ring, of Columbus, Ohio, second vice president; Fayette B. Dow, Washington, D. C., vice president and general council; and Sam Messer, Oil City, Pennsylvania, treasurer; W. R. Roitz, Oil City, assistant treasurer.

W. C. Wenzel of Oil City who recently joined the association as general secretary was elected executive manager of the organization.

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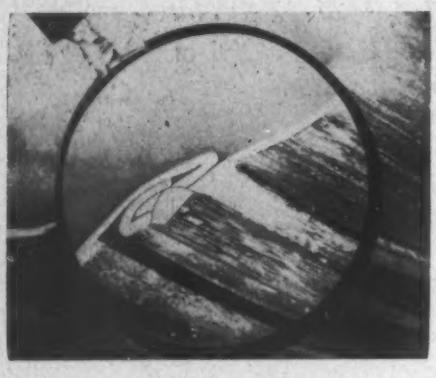
Insulated Pipe Units

The Ric-wiL Company, 1572 Union Commerce Building, Cleveland, Ohio, announces that helical corrugated conduit housing for Ric-wiL prefabricated insulated pipe units is now furnished with a reinforcing full welded lock seam extending spirally the entire length of each section. Automatic machine weld is made at the factory before galvanizing. Sections are 21 feet long, completely fabricated with pipe or pipes as specified, insulation and aligning pipe supports. New drive coupler is adaptable to mechanical or welded closure, with a minimum of field labor.

Conduit is available in several types of construction for piping steam, hot water, oil, hot or refrigerated process liquids. Single pipe systems or multiple systems with any specified combination of pipes are tailored to requirements. Any or all of pipes may be individually insulated to required thickness. Expansion loops, elbows, tees, anchors and all accessories are factory prefabricated.



Ric-wiL Lock Seam

Pump

Milton Roy Pumps, 1315 E. Mermaid Avenue, Philadelphia, announces a step-valve pump with outside spring loading designed specifically for controlled volume pumping against negative differential pressures. Outside spring-loading provides ready adjustment for desired load. The single cover plate is readily removable and provides complete accessibility without disturbing intake or discharge piping. This valve affords complete freedom from air-binding. There is minimum restriction of passages since the pumped liquid moves in an almost straight line under the ball checks, not around them.

This type valve is available with Milton Roy Pumps in capacities from 10 up to 1300 gallons per hour, and is supplied for pumping viscous materials such as liquid latex, acid sludges, tars and asphalts, salt slurries and textile fibres in suspension.

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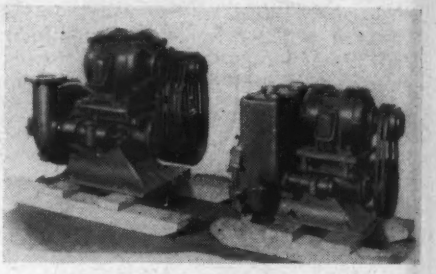
Pump

American Manganese Steel Division of American Brake Shoe Company, Chicago Heights, Illinois, announces that Amsco-Nagle centrifugal pumps of the horizontal type now are available with the motor mounted overhead. Previously these pumps were available with motor directly coupled to the impeller shaft or with V belt pulley, flat pulley or sprocket on the shaft.

The new arrangement offers the following advantages, according to the engineers responsible for its design:



Five-inch Type T at left and two-inch Type A at right—Amsco-Nagle pump with overhead motor.

Pump can be operated at more accurate speeds. Speed changes can be provided where the duty calls for such changes. Motor is stationed at a more accessible point and is at the same time protected against flooding. Less floor space is required.

The manufacturer's Type A and Type T pumps, both horizontal, are available with this motor mounting.

Safety Tread

Truscon Laboratories, Caniff & G. T. R. R., Detroit, Michigan, has developed a slip-proof coating material for floors in industrial plants, or wherever the hazard of slipping exists. The material is a heavy plastic. It comes ready for use and is applied with a trowel to a thickness of about 1/32-inch. It sticks to practically any surface, and on drying imparts a skid-proof walking or working area. It is claimed that the surface treated with this material is skid or non-slip proof even when covered with an oil emulsion. The material may be had in a spark-proof type where non-sparking floors are considered necessary.

Sediment Strainer

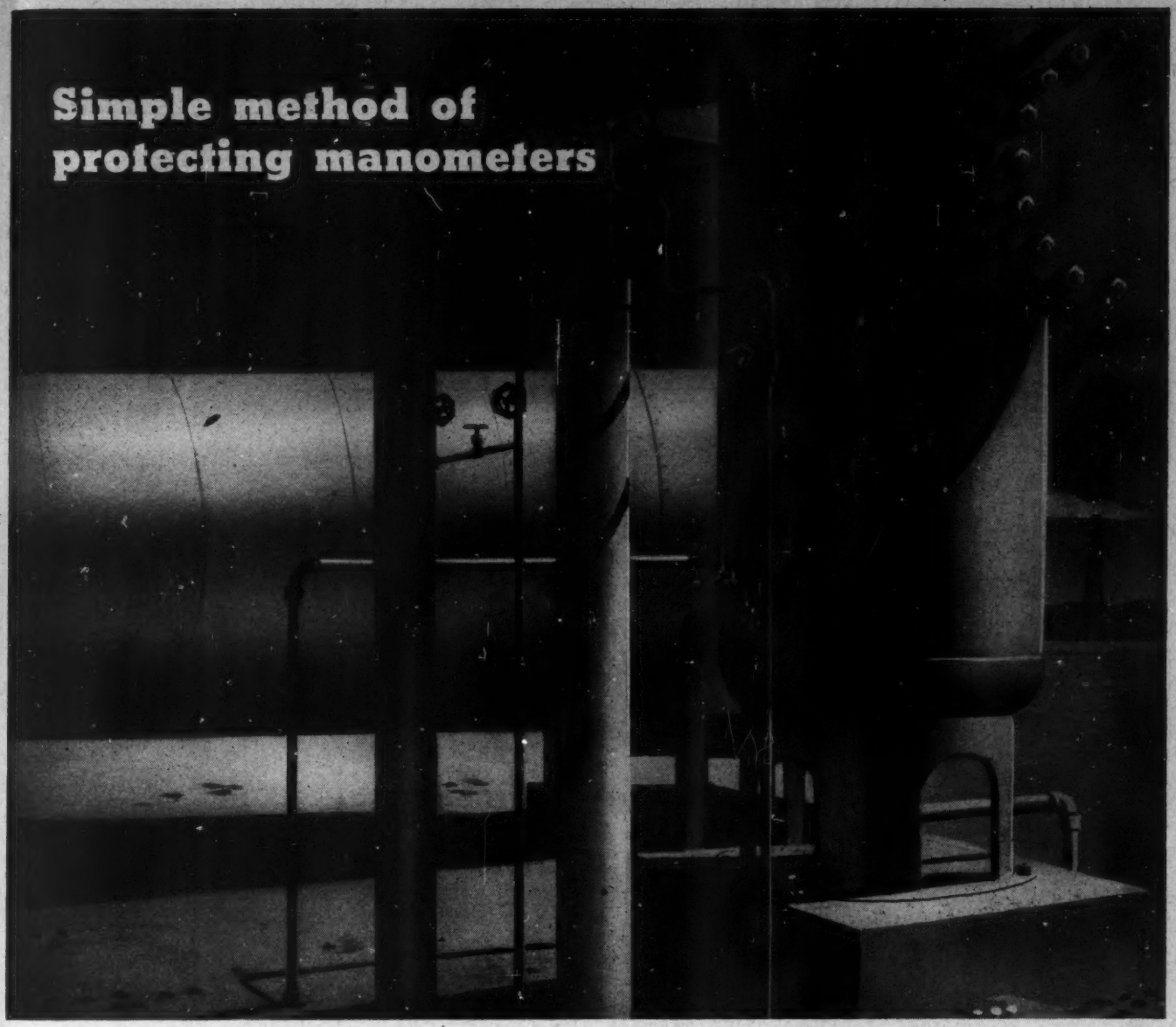
American District Steam Company, North Tonawanda, New York, has announced a new Y type sediment strainer, 125 pounds working pressure, with semi-steel body and removable, perforated, non-corrosive metal screen in pipe sizes from ½- to 2-inch, inclusive, with screwed ends.

Carbon Valve

National Carbon Company, Cleveland 1, Ohio, announces a "Karbate" globe-type corrosion-resistant valve. Addition of this valve to the list of products for the chemical and process industries has made it possible to install complete conveying and heat-transfer systems constructed entirely of "Karbate" chemically inert materials.

The new globe-type valves, like "Kar-

Simple method of protecting manometers



Information supplied by "Petroleum Refiner"

Slotted pipe may be used to protect manometers in refinery installations. Where these instruments have outside locations as in treating plants, they are subject to breakage since it frequently is necessary to use wrenches in changing connections of adjacent piping.

Pieces of 4-inch pipe can be converted into protectors with little difficulty. A slot of sufficient length for the face of the manometer is cut down the length of the pipe. A portion of the cut-away section is turned back inside the pipe as a footing for the instrument.

After setting the pipe in the ground so it will provide sufficient clearance above the ground, the manometer is flanged inside the protector with its face toward the opening. This provides sufficient visibility for observation and protection from breakage.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Molybdenum Company

500 Fifth Avenue • New York City

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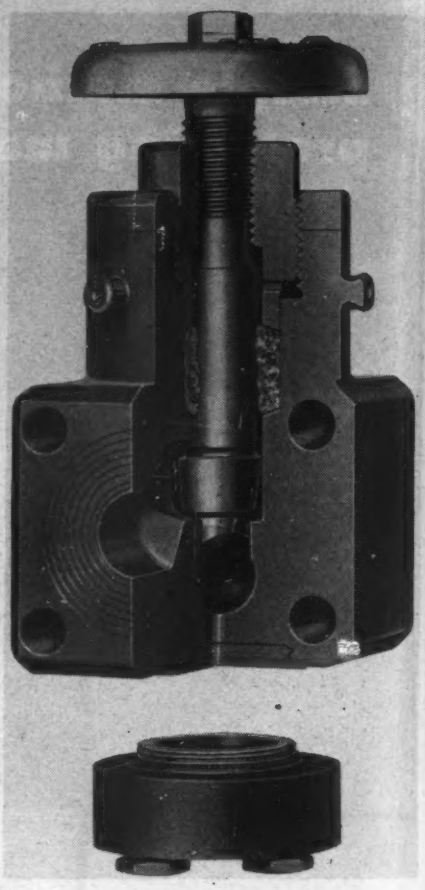
WESTON

all-metal thermometers are used at critical checking points!

● At this new Cities Service refinery the familiar, legible faces of WESTON temperature gauges appear at hundreds of critical checking points. Here, too, their selection was based not alone on the extreme legibility of their boldly marked gauge-type scales, but also on their *proved* all-metal temperature principle. This all-metal construction contributes extreme ruggedness, of course; but it also enables these thermometers to maintain their high initial accuracy *far longer* . . . because of the absence of gases, liquids, capillaries, and other troublesome parts.

WESTON all-metal temperature gauges are available in various sizes and stem lengths for industrial applications . . . as well as in models for laboratory use. Ask for literature today . . . Weston Electrical Instrument Corporation, 655 Frelinghuysen Ave., Newark 5, N. J.

WESTON *All Metal* TEMPERATURE GAUGES



"Karbate" Valve

bate" tanks, heat exchangers, pipes, fittings, towers, and pumps, are resistant to practically all corrosive chemicals and are unaffected by extreme thermal shock.

The valves are available in 1- and 2-inch sizes. Tested to withstand 50 pounds pressure, they are uniquely small and lightweight, with short face-to-face dimensions. "Karbate" valves are of graphite stock and are self-lubricating. The inert chemical properties of the material prevents corrosion-caused sticking of the moving parts, thereby cutting down the maintenance normally required to keep valves operating at full efficiency.

"Karbate" valves are equipped with adapter plugs for steam-heating those fluids that tend to crystallize or solidify when handled through unheated lines. Utilization of the adapter plugs for steam-heating the valve will prevent clogging and avoid shut-downs while vavles are dismantled and cleaned.

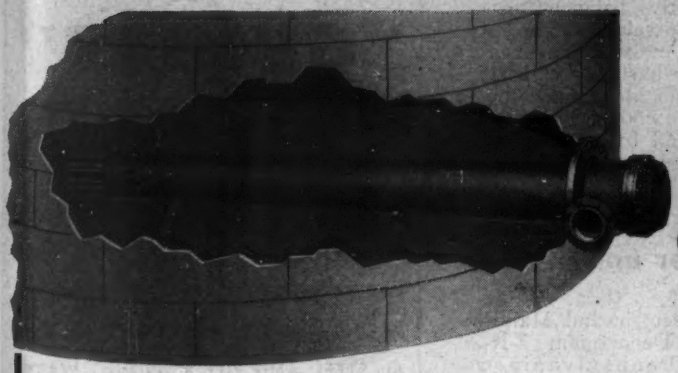
Metallizing Gun

Metallizing Engineering Company, 1830th Street, Long Island City 1, New York, has announced a metallizing gun for high-speed spraying of low-melting-point metals. Applications recommended include corrosion-resistant coatings on steel structures and chemical-resistant linings for tanks.

Air Cleaner

Bird-White Company, 3119 W. Lake Street, Chicago, has developed a new Pur-O-fier, a device for purifying compressed air. The apparatus operates on a centrifugal principle, utilizing a high velocity turbo-rotor.

The air entering from the intake pipe



Whitlock Suction Type Oil Heater Unit Riveted in Storage Tank

WHITLOCK
Suction Type
OIL HEATERS
Ready for Installation

With the Whitlock Suction Type Heater, oil is heated as it is drawn from storage tank, permitting pumps to work at full efficiency: there's no need to heat entire contents of tank. The Whitlock Suction Heater unit, available in several sizes, is furnished ready to weld, rivet or bolt to the storage tank, complete with heating section of steel tubing, steam distributing head and suction connection. *Whitlock's* long experience in making heat transfer equipment is your guarantee of efficient design and sound construction. For recommendations, send complete information.

Our new booklet "The Care and Handling of Heat Exchangers" is available upon request.

The WHITLOCK MANUFACTURING CO.

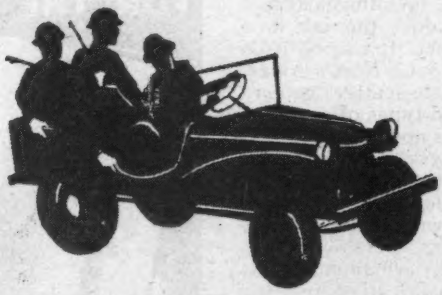
75 SOUTH ST., ELMWOOD, HARTFORD 1, CONN.

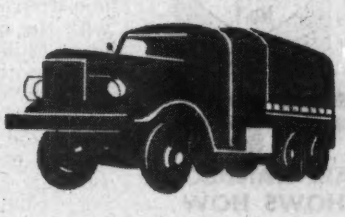
Branch Offices: New York, Boston, Chicago, Philadelphia, Detroit, Richmond

Authorized representatives in other principal cities — consult local telephone directory under our name.
Whitlock Equipment (Whitlock-Darling) is manufactured in Canada by Darling Brothers, Ltd., Montreal.

To Refiners Contemplating the Manufacture of

80 OCTANE ARMY ALL-PURPOSE GASOLINE





GRAY Catalytic Desulfurization will insure maximum production of blended straight run and cracked distillates leaded to 3 c.c. Tetra Ethyl Lead and bring oxidation stabilities well within inhibitor control.

THE GRAY PROCESSES CORPORATION

26 JOURNAL SQUARE · JERSEY CITY, N. J.

SMOOTH-ON
REPAIR
RECORDS
Cracked Engine Block
This crack in the water jacket of an internal combustion engine kept getting worse. Welders would not guarantee the results of welding. The edges of the crack were slightly widened by a cold chisel, the crack was thoroughly cleaned, and SMOOTH-ON No. 1 was tamped in. The SMOOTH-ON repair has kept the engine block tight ever since.
SMOOTH-ON
FOLLOW THIS SERIES OF SMOOTH-ON SAVINGS

In this particular instance, the repair was first considered temporary, but the engineer now knows, like many thousands of others, that SMOOTH-ON repairs are *lasting*.

In innumerable other cases, too, SMOOTH-ON has helped to keep important equipment in operation, and has avoided delays that would have resulted from trying to obtain new parts. SMOOTH-ON is the long-established stand-by of engineers all over the country for stopping leaks, sealing cracks, and tightening loose parts of equipment, fixtures, and structures. Does not require dismantling of apparatus or application of heat, and produces dependable results.

Buy SMOOTH-ON in 7-oz., 1-lb., or larger containers from your supply house, or if necessary, from us. For your protection, insist on SMOOTH-ON, used by engineers and repair men for over 50 years.

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REPAIR HANDBOOK SHOWS HOW

40 pages, 170 diagrams, and simple concise instructions for practical repairs to plant equipment, pipe lines and structures. A necessity in every plant. Your copy sent FREE if you fill in and return the coupon.

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Do it with **SMOOTH-ON**
The Iron Repair Cement of 1000 Uses

rotates a high speed, positive, noncushioning, perfectly balanced rotor, which is sensitive to velocity. The rotor beats the atomized moisture and vaporized oil into larger particles which are driven outward and downward by a shroud. As they are cooled the entrainments are drained off by gravity into a reservoir designed for manual operation. Units provided with automatic draining are also available.

Welding Timer and Heat Control

Westinghouse Electric and Manufacturing Company, Department 7-N-20, East Pittsburgh, Pennsylvania, announces a new precise welding timer with heat control for timing intervals of ½ cycle or less, suitable for welding small objects of high conductivity such as aluminum or copper.

Precise, because the welding current is made to start at the same point on the voltage wave for every operation, the new SP-18, ½-cycle timer is designed for welding of such items as radio tube parts and sockets, pig-tail resistors to terminal lugs, watch and instrument parts, contact tips on electrical relays and other small parts.

The timer is furnished as a separate control for use with existing small bench welders and also in combination with a small welding transformer. Only one control tube is used, this thyratron serving the dual purpose of rectifying alternating current to charge a firing capacitor and also firing the small ignitron power tube. Heat control is accomplished by a phase shift method, the adjustment dial for which is mounted on the cabinet door.

X-Ray Diffraction Unit

North American Philips Company, 100 East 42nd Street, New York 17, announces an X-ray diffraction unit designed for readily solving analysis problems formerly considered impossible in the chemical, metallurgical and scientific fields, and does the job in a non-destructive manner. It can be used with the newly-developed North American Philips low-angle-scatter camera or with other standard types of cameras.

"X-ray diffraction is not new in itself," an announcement says. "However, the utilization of new accessories and techniques now available will prove invaluable in the following fields: Welding, casting, forging, ferro-concrete, plastics, asphalt, oil, armaments, aircraft, locomotives, coal, leather, textiles, ceramics, chemical, plywood, steel valves, high-pressure tanks, porcelain, cables, rubber, food (cheese, ice cream), rope, precious stones, and radio.

"The new 'Norelco' X-ray diffraction unit has a four-windowed tube enclosed in a massive bronze housing. Diffraction patterns of four different specimens can be obtained simultaneously. A number of types of X-ray tubes can be provided, included in which are targets of tungsten, molybdenum, cobalt, iron, chromium and copper. Tubes can be changed quickly, usually in 2 minutes, using only a screwdriver.

"Fully shockproof and rayproof, the unit utilizes full wave rectification which permits higher output and longer life from the tube. Filament current supply is stabilized, control of kilovoltage and milliamperage is smooth and stepless,

"GUNITE"

CONCRETE LININGS

FOR:

BUBBLE TOWERS • STILLS • HOT OIL SEPARATORS • STORAGE TANKS • REFINERY VESSELS OF ALL TYPES • ENCASING AND FIREPROOFING STRUCTURAL STEEL AND PIPE • LINING WATER STORAGE RESERVOIRS, DITCHES AND CANALS • REPAIRING DISINTEGRATED CONCRETE AND MASONRY.

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SIDE ENTRANCE MIXERS
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BLENDERS, PEBBLE & BALL MILLS
INTERNATIONAL ENGINEERING, INC
DAYTON, OHIO

OF THE COMPLETE LINE...

PYREX HIGH PRESSURE

for use where Temperature Changes are Extreme

You can't use just any Gauge Glass where thermal shock may be encountered—and expect it to stand up. PYREX High Pressure Gauge Glasses are built to withstand sudden temperature changes. In a routine test at Corning, they are heated to 425° F. and plunged into ice water.

They have an exceptionally long life and retain their original crystal clearness, because the special borosilicate glass from which they are made resists the solvent action of steam and hot water. The hard, smooth surface resists scratching.

Because PYREX brand Gauge Glasses are made with machine drawn accuracy, they fit right—there's very little possibility of installation strains.

Pick the one Gauge Glass best suited for your particular requirements from the complete CORNING and PYREX line. Write for Bulletin 817; it tells the whole story on all these glasses and helps you select the right glass for your service. Industrial Division, Dept. PR2, Corning Glass Works, Corning, N. Y.

"Pyrex" is a registered trade-mark and indicates manufacture by Corning Glass Works, Corning, N. Y.

PYREX brand High Pressure—resistant to thermal and mechanical shock and attack of steam and hot water. Machine drawn accuracy.

PYREX brand Red Line—Same but with added visibility afforded by enameled red line.

PYREX brand Broad Red Line—Same but with fused-in broad red line for extra visibility.

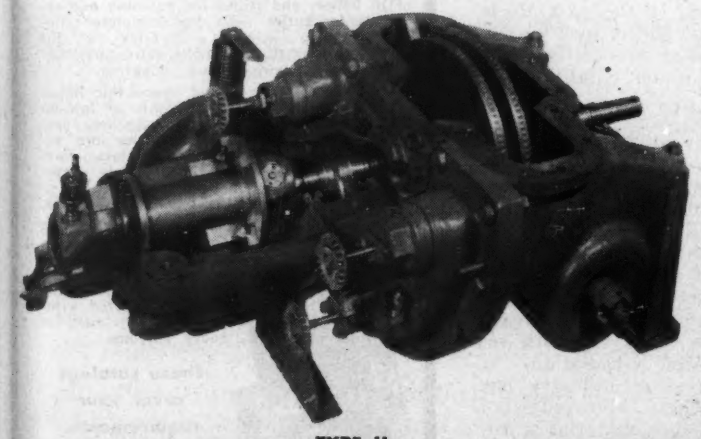
CORNING Standard—For moderate pressures. Long-lasting. Machine drawn accuracy.

CORNING Glass Works Corning, New York

Pyrex Gauge Glasses

MURRAY

SINGLE STAGE TURBINES FOR MECHANICAL DRIVE



TYPE U

Are built in a variety of wheel sizes, with either two or three-row impulse type wheels, with all materials suitable for your operating conditions. May be furnished with any type of governor, for constant or variable speed operation.

Type "U" Turbines are designed to have ruggedness expected of single stage turbines, plus ease of disassembly. Ask for Bulletin T-118.

Other Murray Products:

Turbine-Generator Sets
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Multistage turbines, Type UV
Vertical Turbines, direct connected and geared
Steam Boilers

Branches in all Principal Cities

MURRAY IRON WORKS COMPANY

BURLINGTON, IOWA

BUILDERS OF STEAM POWER EQUIPMENT FOR THREE QUARTERS OF A CENTURY

Plastics

BAKORINGS

Made of

LAMINATED PHENOLIC PLASTICS

As the plastic material of these rings is practically self-lubricating, temporary loss of lubricant will not affect the life of the piston rings or the liners.

Grit and scale become embedded in the plastic and do not scrape liner as with metal rings.

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SHOCK RESISTANCE . . . RESISTANCE TO ABRASION AND WEAR . . . HIGH STRENGTH WITH LOW WEIGHT make Phenolic Plastics ideal for:

• Bushings • Bearings • Electric Insulators
• Wearing Rings in Centrifugal Pumps
• And Many Other Products

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ENGINEERS familiar with these excellent properties of Laminated Phenolic Plastics are daily finding more and more advantageous uses for them.

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LARGEST STOCK of Tubing and most comprehensive stock of Laminated Phenolic Rods and Sheets in the Southwest.

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Proved by leading companies to give lower service cost per hour

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QUICK DELIVERY . . . WRITE FOR FOLDER AND PRICES

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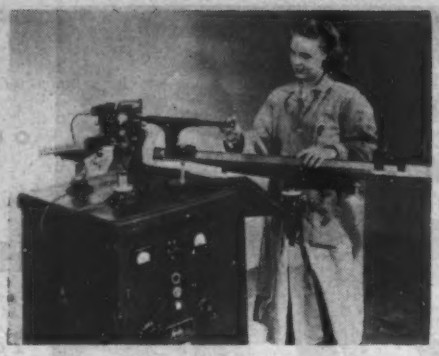


Low-angle-scatter camera with operator ascertaining correct placement of specimen in specimen holder. Note also other tracks and cameras in position.

tube is protected automatically if water supply fails, equipment has start-stop push-button control, and provision is made for use of automatic exposure timer.

"The slanted panel is indirectly lighted for easy observation and carries, in addition to controls mentioned above, a 0-50 milliampere meter, main-line switch with overload circuit breaker, calibrated peak-kilovoltage selector, and a pilot lamp. There is also an elapsed-time meter (calibrated in hours and tenths of hours) that serves for long exposures and for recording tube life.

"The X-ray diffraction unit is fully shockproof, due to interlocking switches which prevent the transformer from being energized when sides of the unit are open. Precision optical-type camera tracks are available as optional equipment. Adjustments and associated locking devices for adjusting cameras are positive in action. Tracks and supports can be removed readily, leaving the table top clear for use with special apparatus such as the Weissenberg goniometer.

"The low-angle-scatter camera is a most outstanding recent development of the North American Philips organization. For example, with this accessory, X-ray diffraction can now differentiate between hard and soft chrysotile in asbestos fibres coming from different geographic locations. In the past, these silky fibers were alike by known methods of analysis—yet showed marked differences under conditions of application.

"Circular powder cameras are also available for use with the Norelco analyzer. They have either 57.3 or 114.59 mm. effective diameters, and size of small camera is such that 1 mm. of distance between diffraction lines on film corresponds to 1° Bragg angle. On the large camera, 1 mm. between lines on the film corresponds to ½° Bragg angle. Focussing cameras also are available as well as flat types for both reflected and transmitted X-radiation.

"Technical progress in industry has reached a point where knowledge of the structure of a given material is important. The chemical identification of materials, phase analysis in chemical processes, the presence or absence of preferred orientation in metals or fibers, particle size determination of fine materials—such as catalysts, carbon blacks, rubber fillers and other substances, the goniometric data of crystals, and a host of other problems can now be solved by X-ray diffraction equipment."

Rotary Pumps

Goulds Pumps, Inc. Seneca Falls, New York announces a line of rotary pumps of the double-helical or herring-bone-gear type, designed to handle liquids with inherent lubricating qualities. The pumps are available in 10 sizes from ½-inch suction and discharge, capacity 1 to 1½ gallons per minute, to 2½-inch with capacity from 50 to 75 gallons per minute. Maximum working pressures in all sizes is given as 75 pounds. All sizes are obtainable for direct drive through flexible coupling or for belt drive.

Construction involves but two moving parts, a split bolted type gland, renewable bearings and built-in relief valve.

The rotors are accurately bored and pressed onto the shaft. The driven gear is of bronze while the driving gear is of steel held by a key.

Bearings are of high lead bronze fitted with grease lubricators. The extra deep stuffing box is fitted with metallic packing. The bronze gland is split in halves for easy removal and is held together by two fitted bolts.

The relief valve of the stainless steel ball type is built into the pump cover and is externally adjustable.

In addition to the standard fitted type all pumps are also available with all parts of iron or steel or in all bronze construction.

FOR SALE: Steel gate valves, mostly flanged, some 300, 600, 900, and 1500 pound. Sizes 2, 2½, 3, 4, and 6 inch various pressures. Special trim if desired. Also few globe valves.

MARVEL VALVE REPAIR COMPANY
8316 La Porte Road Houston 12, Texas

PLIBRICO
Jointless FIREBRICK

The Answer to Your Refractory Problems!

FOR boilers and stills—for patching and repairs—for entire walls and complete relining—Plibrico Jointless Firebrick is the dollar-saving, trouble-saving refractory that refineries everywhere are adopting.

Plibrico forms a solid, monolithic lining that eliminates the weak joints of laid-up fire brick construction. Flexo-Anchors prevent bulging. No special shapes are required; Plibrico comes in moist, plastic form and can be readily moulded to any shape. Your own maintenance men can install it or we furnish complete installation service.

For extreme conditions, there is the Plibrico sectionally-supported air-cooled wall. And the Plibrico suspended arch for boiler arches and still roofs. Both are erected without special tile or heavy castings.

These catalogs cover your requirements.

Here is the complete story of Plibrico linings, arches, air cooling, etc. Ask for your Plibrico catalog. Specify whether operating H.R.T. or water tube boilers.

PLIBRICO JOINTLESS FIREBRICK CO.
1803 Kingsbury St., Chicago, Illinois

For HIGH TEMPERATURE VAPOR and SATURATED STEAM LINES...

...ZALLEA CORRUGATED PACKLESS EXPANSION JOINTS

Self-equalizing rings on Zallea Expansion Joints distribute the movement equally over the entire length, preventing any single corrugation from taking more than its share of compression. The rings also serve to support the element against internal pressure.

Zallea Expansion Joints are furnished in sizes up to 30" diameter and for any desired traverse up to 7½" in a single unit, with flanged or welding ends. Flanged ends may be vanstone or ring joint type as desired. For use on vapor-phase and catalytic cracking high temperature lines corrugated elements are made of stainless steel of proper alloy to withstand temperatures up to 1800° F. For saturated steam lines corrugated elements are made of specially heat treated copper.

We are in a position to fabricate special expansion joints to meet practically any condition of pressure, temperature and corrosion, and stand ready to consult with you on either standard or special requirements.

"Code-Craft"...

ZALLEA BROTHERS & JOHNSON

...EQUIPMENT FOR THE PROCESS INDUSTRIES

890 LOCUST ST., WILMINGTON 99, DEL.

Better Way to Wash Overalls, Rags, Waste

Would you like to greatly improve results when washing wiping cloths, cotton waste, overalls, coveralls, etc.? Here's the answer:

Use Oakite Penetrant in your tank or laundry wheel, as directed. Combining fast wetting-out and extraordinary solvent characteristics, this specially developed material quickly dissolves grease, dirt and grime . . . steps up soil removal . . . provides more WASHING ACTION . . . delivers wiping cloths and work clothes that are clean and absorbent. Not only is Oakite Penetrant rapid-acting and effective but economical too!

Data FREE on Request

Because conditions vary greatly in this work, let us recommend proper formulas for your job! There's no obligation, so write TODAY!

OAKITE PRODUCTS, INC.
508 Thames Street, New York 6, N.Y.
Technical Service Representatives Located in All Principal Cities of the United States and Canada

☆ BUSINESS NOTES ☆

The Babcock & Wilcox Tube Company announces addition to its staff, as research metallurgist, of Marcel A. Cordovi, formerly research assistant, Welding Research Council of the Engineering Foundation. Cordovi received his BME and MME degrees from the Polytechnic Institute of Brooklyn where he held a Graduate Fellowship in 1941 and worked on numerous research projects with Professor Otto H. Henry.

Jones & Laughlin Steel Corporation, Pittsburgh, announces that its subsidiary, J. & L. Steel Barrel Company, has purchased the physical assets and business of Draper Manufacturing Company of Cleveland.

The Draper Division of the J. & L. Steel Barrel Company will be operated under the present managing personnel.

J. F. Mitchell-Roberts, manager of the foreign and export division of Oliver United Filters Inc., is resigning his position with the company. Since 1920, his duties have taken him over most of the world in serving the metallurgical, chemical and process industries in connection with filtration and clarification problems.

Fisher Governor Company, Marshalltown, Iowa, announces appointment of The Sullivan-Mears Company as its representative in Kansas and Western Missouri, with offices at 215 Pershing Road, Kansas City. H. W. Sullivan, for the past few years, has been employed by Briggs Clarifer Company as zone manager in the Mid-Continent. He has had experience in the oil and gas industries with Phillips Petroleum Company and with Bethlehem Steel Company, particularly in refinery construction and operation work. Because of his five years association with the Fisher organization, L. A. Mears is well known in the Kansas City territory.

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has purchased Electric Machinery Manufacturing Company, Minneapolis, Minnesota. The latter will continue to operate independently of Worthington's other activities. The two companies heretofore have collaborated in assembly of power units where Electric Machinery motors drive Worthington pumps and compressors, and Worthington engines drive Electric Machinery generators.

The Cooper-Bessemer Corporation, Mount Vernon, Ohio, and Grove City, Pennsylvania, announces appointment of William F. Lamoreaux as research metallurgist.

W. F. Lamoreaux

Lamoreaux, who for the past three years was director of research for Meehanite Metal Corporation, will divide his time between the company's two plants. At the outset, he will undertake closer integration of the company's engineering, metallurgical and foundry efforts.

In addition to his research work, Lamoreaux will specialize in exploring the application of high-duty iron castings to various phases of industry, particularly in the mining and heavy chemical fields.

Moorlane Company, Tulsa, announces appointment of C. W. Harrington to its refinery equipment sales staff. He served as district sales manager at Tulsa for Mexico Refractories Company for 7½ years, and for the last 2½ years has been in the company's home office in charge of dealer and distributor business.

C. W. Harrington

Alco Products Division's manager, Hugh M. Corrough, was elected chairman of the executive committee of the Pipe Fabrication Institute at the thirty-first annual meeting of the committee recently at Pittsburgh. The institute, devoted to technical and economic problems in industrial piping, has a membership of representatives of a score of companies.

L. J. Wing Manufacturing Company, 154 West 14th Street, New York 11, announces appointment of the following new representatives: Glidden Engineering & Equipment Company, Dallas and Austin, Texas; E. Lloyd Widner, Knoxville, Tennessee; Babcock & Wilcox, Ltd., of Mexico, Mexico City, and Sergio Ortiz Toro, Caracas, Venezuela.

Westinghouse Electric and Manufacturing Company has appointed C. P. Croco manager of a newly formed Welding Department of the Motor Division at the Trafford, Pennsylvania, Works, Croco, who ended an 18-year association as an engineer with the company in 1943, to become director of engineering for Federal Machine & Welder Company at Warren, Ohio, returns to the company to assume responsibility for engineering, manufacture and sales of all arc-welding equipment and electrodes manufactured at Trafford.

The J. B. Beaird Company, Shreveport, has opened a branch office at 305 Citizens State Bank Building, Houston, under the management of Hubert B. Wilder, who for many years has been active in South Texas oil operations. Wilder will handle sales and service in the territory on equipment for the oil and chemical industries, including pressure vessels, fractionating columns,

H. B. Wilder

FOR THE *Difficult Fluids* SPECIFY REED *Quarter-turn Double Disc Gate* VALVES

QUARTER-TURN FOR QUICK OPERATION • STRAIGHT FLOW • POSITIVE SHUT-OFF • EASY OPERATION

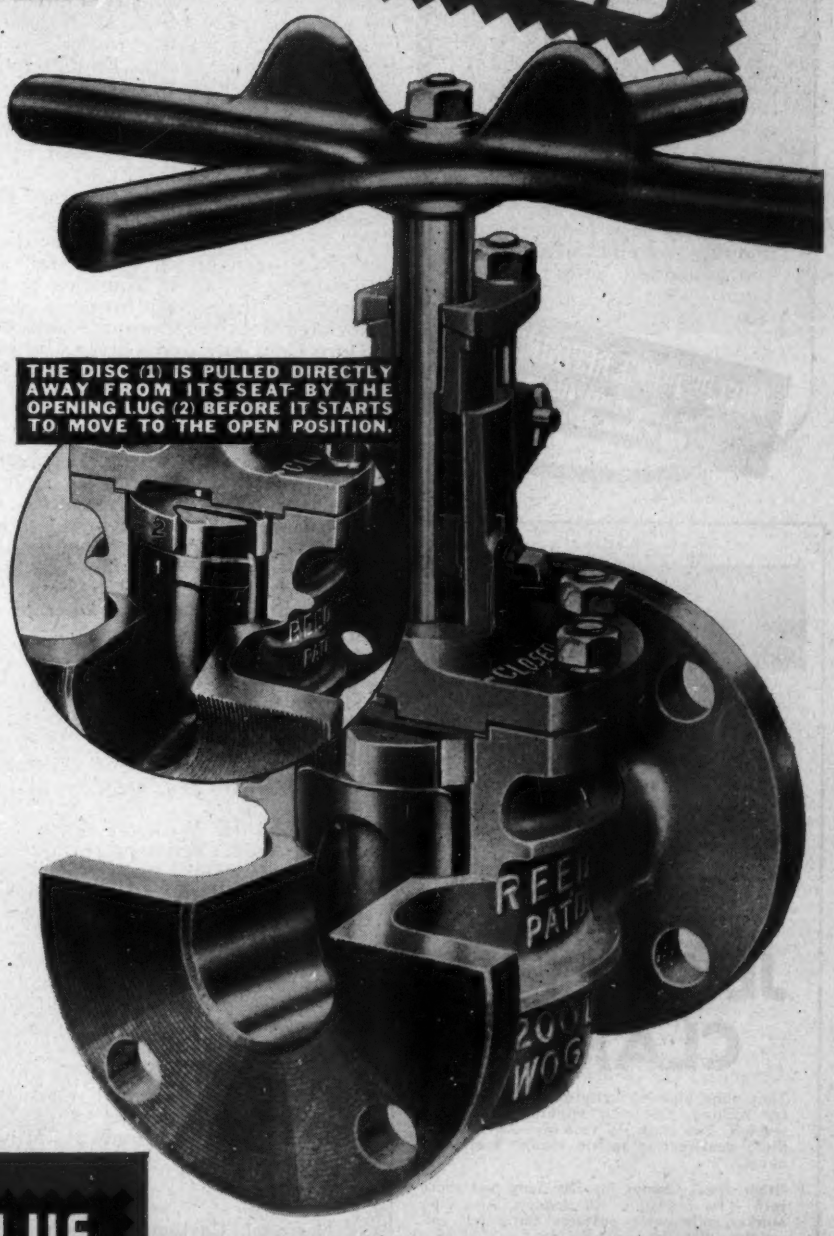
These are only a few of the advantages to be found in Reed Steel Valves for your hard-to-handle fluids.

Reed Valves are designed and constructed to provide ease of operation and positive shut-off under the most severe service conditions, with the greatest factor of safety.

The through-conduit in the disc holder decreases pressure drop. Heavy walls give greater strength. The cleaning action of the discs assures tight, positive seating. Deep stuffing boxes prohibit leakage and insure a minimum of frictional resistance between the packing and the stem.

Available in corrosion resistant trims.

On your next "tough" valve problem, consult a Reed engineer . . . or one of the distributors listed below.


THE DISC (1) IS PULLED DIRECTLY AWAY FROM ITS SEAT BY THE OPENING LUG (2) BEFORE IT STARTS TO MOVE TO THE OPEN POSITION.
2
1
REED PAT.
CLOSED

Reed VALVE DIVISION
ROLLER BIT COMPANY
HOUSTON 1, TEXAS

41-2

REPUBLIC SUPPLY CO.
LOS ANGELES, CALIF.

SOUTHERN SUPPLY CO.
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PITTSBURGH, PA.

TAYLOR SUPPLY CO.
DETROIT, MICH.

PEDEN IRON & STEEL CO.
HOUSTON, TEXAS

ESPECIALLY RECOMMENDED FOR USE IN THE

COPPER SWEETENING PROCESS

Nichols

TRIANGLE BRAND

COPPER SULPHATE

is preferred by leading refineries because of its high copper content, dependable uniformity and exceptional purity and freedom from foreign and inert matter.

99% + PURE

Quotations on request, on any quantity required. Shipments can be made from our nearest plant.

PHELPS DODGE REFINING CORP.
40 WALL STREET, NEW YORK
230 N. MICH. AVE., CHICAGO

heat exchangers, flanged steel fittings, commercial castings, and many other items. Already familiar with the territory and the industry, Wilder spent six weeks in the shops at Shreveport, learning the company's stocks, facilities and processes before taking charge of the Houston office.

Peerless Pump Division of Food Machinery Corporation, Los Angeles, announces appointment of Clarence Frazier as manager of the division. Frazier joined the corporation in 1941 as assistant to the president and has advanced to vice president. He succeeds the late Vernon Edler as manager of the division.

The Brown Instrument Company announces appointment of Al J. McCullough and Jack E. MacConville, to be in charge jointly of industrial instrument sales, with headquarters at Cleveland, Ohio. McCullough has been with the Cleveland branch for the past eight years, and MacConville has been with the company for the past 15 years.

General American Process Equipment, 420 Lexington Avenue, New York, announces that Roman Chelminski has been added to its staff as assistant to Dr. C. L. Knowles, technical director. Chelminski formerly was associated with the European activities of Dorr Company and Oliver United Filters, Inc., and more recently was a member of the sales staff of Dorr Company.

The Brown Instrument Company has named V. H. Hiermeiser industrial manager of its St. Louis office, where he succeeds I. K. Farley. Hiermeiser has had 15 years experience in the industrial-instrument field, and is credited with doing much to help Purdue University establish and operate an instrument course.

Oil Well Supply Company, United States Steel subsidiary, has acquired Witte Engine Works, Kansas City, Missouri. Witte Engine Works will continue as heretofore in the manufacture of small gas, gasoline and diesel engines.

Edward H. Witte at the age of 77, retires from active direction of the company, which was started by his father in 1870 and from whom he purchased it in 1886.

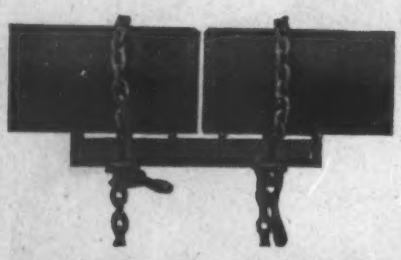
Ampco Metal, Inc., Milwaukee, has built a new plant at 30 East Burbank Boulevard, Burbank, California, at which West Coast activities of the company will be concentrated. The new plant will produce Ampco metal by both the centrifugal and sand-cast process, and extruded and other wrought products manufactured at Milwaukee will be stocked, as will a supply of nonsparking tools.

National Carbon Company has announced a new sales set-up under which all company products will be handled nationally from seven divisional offices. Four of the new offices are in operation and the others will be added by October 1.

All sales activities in the Southeast have been consolidated under a new Atlanta division office. This division will comprise Georgia, Virginia, North and South Carolina, Alabama, most of Tennessee, and Florida. J. F. Warnell, former manager under the "district" system and recently stationed at New York, has returned to Atlanta as division manager. The assistant manager is C. J. Chapman, who has been in company sales for the last 10 years, and W. R. Peppard is office supervisor. The organization is using the former district address—41 Marietta Street, Atlanta 3.

C. C. Joslyn is manager of the new Dallas, Texas, division. He has been with the company more than a decade. Assistant manager is J. L. Mullen, recently district manager at Atlanta, and J. F. Uhl is office supervisor. The former district offices at 200 South Ervay Street, Zone 1, have been retained. This division will comprise Texas, Arkansas, Oklahoma, New Mexico, Mississippi, Louisiana, and part of Tennessee.

At Kansas City, A. C. Bryan has taken over as division manager. He has been with the company for 10 years as salesman and sales executive. E. L. Dibble, former manager of the district



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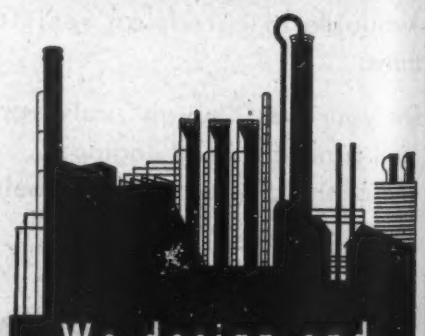

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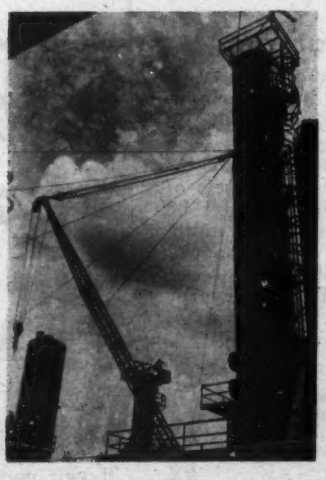

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there is assistant manager. C. H. Wade is supervisor of the new offices, which occupy the same location, 19th and Campbell Streets, Kansas City 8. The division will comprise Missouri, Kansas, South Dakota, Wyoming, Nebraska, Colorado, Western Illinois, and most of Iowa. Orders from electrode and anode customers in the Kansas City Division will be received at the Dallas office.

On the West Coast, R. P. Tolles, manager of the former Pacific Coast division, succeeds to the direction of the new San Francisco organization. The assistant managers are A. R. Miller, former district manager at Portland, Oregon, and O. B. Rendahl. The new division staff will occupy the old address at 114 Sansome Street, San Francisco 4, and from this headquarters will be directed sales in California, Washington, Oregon, Western Montana, Idaho, Utah, Arizona, and Nevada.

The three division offices yet to be opened will be located at Chicago, Pittsburgh and New York. Much enlarged staffs will be active in all the divisional headquarters.

The Philip Carey Manufacturing Company, Cincinnati, Ohio, has announced the appointment of C. B. Pooler as vice president in charge of manufacturing. The company operates nine plants in the United States and Canada.

Ira G. Whitney, president of A. Y. McDonald Manufacturing Company, Dubuque, Iowa, died June 11. He was born in Brooklyn in 1877, came to Dubuque shortly after the turn of the century and in 1908 became associated with the company whose destinies he was later to guide as president.

Richard O. Miller, with The Terry Steam Turbine Company, Hartford, Connecticut, since 1915 and its chief engineer from 1926 until retirement a few months ago because of ill health, died June 4.

To Sell Surplus Material

Defense Plant Corporation, Materials Division, plans disposal of excess construction material and equipment on DPC properties. A program has been instituted to expedite return of surplus pipe, valves and fittings to channels of normal distribution. Proposals will be accepted for the purchase of all materials regarded as surplus. Large quantity proposals are preferred since office personnel is insufficient to handle large numbers of small orders. Inventories of materials are on file for inspection.

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